THE IMPACT OF USING ELEMENTARY SCIENCE SPECIALISTS ON 5TH GRADE SCIENCE ACHIEVEMENT SCORES

by

Wesley Armstrong Roach

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

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APPROVED BY:

Jillian Wendt, Ed.D., Committee Chair

Philip Alsup, Ed.D., Committee Member

Davis Nelson, Ed.D., Committee Member

ABSTRACT

American students score significantly below several other countries in the area of science achievement. With threats such as epidemics and cyber terrorism facing modern society, it is important for schools to prepare students to succeed in science. Research has shown, however, that substandard science instruction at the elementary level leaves students ill-prepared for future success in science. And, even worse, low quality science instruction in elementary school is, for some students, correlated to the loss of interest in science altogether. The purpose of this causal-comparative study was to examine the effect of using science specialists in elementary schools on science achievement scores. The author conducted an Analysis of Covariance (ANCOVA) to determine if there was a difference between science achievement scores in elementary schools that use science specialists as opposed to those that do not. The population consisted of 282 5th grade students in Georgia public schools. The researcher collected data for this study from four public elementary schools' end-of-year state assessments.

Keywords: science specialist, generalist, instruction, elementary science, science achievement

Dedication

I would like to dedicate this study to my wife, Leah, and to my children, Ashton and Sadie. My wife and children have been my greatest sources of inspiration and encouragement. Any accomplishments for which I may be credited have only been possible because of my family. I am thankful for their love and support.

Acknowledgments

I would like to acknowledge the work of a couple of my colleagues that relates to the ideas that led to the topic of this study. In 2004, I was an eighth grade science teacher, and I worked with Laurie Brown, who was a seventh grade science teacher. She was the first person from whom I can recall hearing about the idea of an elementary science specialist. At that time, as I recall it, she told me how much she would enjoy the opportunity to be a science specialist in an elementary school, where she would like to prepare laboratory experiences for students that would cultivate in them an appreciation for science. Secondly, I would like to acknowledge the work of another colleague, Gayla Pierce, who, at the time of this study, was the only elementary science specialist with whom I had worked. She demonstrated an indefatigable commitment to bringing science to life for hundreds of elementary students during her years of service. Finally, I would like to acknowledge God, the author of all truth, who miraculously instituted science and natural law. It is from Him that I draw my strength and inspiration.

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List of Abbreviations

Analysis of Covariance (ANCOVA)

Constructivist Learning Model (CLM)

Disciplinary Core Ideas (DCI)

English Language Arts (ELA)

Georgia Department of Education (GaDOE)

Georgia Milestones Assessment System (GMAS)

Georgia Standards of Excellence (GSE)

Individuals with Disabilities Education Act (IDEA)

Individual Education Plan (IEP)

Inquiry Based Learning (IBL)

School grades kindergarten through 12 (K-12)

National Research Council (NRC)

Next Generation Science Standards (NGSS)

Parent Resource Center (PRC)

Program for International Student Assessment (PISA)

Science, Technology, Engineering, and Math (STEM)

Science, Technology, and Society (STS)

Technical Advisory Committee (TAC)

CHAPTER ONE: INTRODUCTION

Overview

This study will examine the use of elementary science specialists for the delivery of science instruction to fifth grade students in Georgia. Most elementary students learn science from their regular education teachers, many of whom are not science specialists, but rather subject generalists. This study is designed to consider the effect of using elementary science specialists on the science achievement of fifth grade students. In this chapter, background information related to this study will be provided. The problem statement and the purpose statement will be presented. The significance of the study will be explained. The research question to which this study responds will be shared. Finally, key terms related to this study will be defined.

Background

It is essential that elementary schools provide quality science instruction so that more students will be likely to develop interest in science and to perhaps eventually pursue degrees and careers in science related fields. According to Olson and Riordan (2012) the need for qualified persons to enter science-related careers over the next few years in the United States far exceeds the current rate at which qualified candidates are being prepared for and entering these careers. Unfortunately, the current state of science education in the United States is not optimal, with American high school graduates achieving below their peers around the world and with most American adults being deficient in the area of science literacy (National Research Council, 2013). Studies have shown that students engage more and develop more interests in science when the class is taught in an engaging manner (Campbell & Chittleborough, 2014; Hanuscin, 2007; McGrew, 2012; McNeill & Pimentel, 2010; Smith, Trygstad, & Banilower, 2016).

Furthermore, students who have the opportunity to practice authentic science are more likely to develop a higher level of scientific literacy (Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Jones, Childers, Stevens, & Whitley, 2012; Qarareh, 2016). Unfortunately, elementary students who are not afforded engaging experiences in science are not likely to develop strong scientific literacy, nor are they likely to recover from their deficiencies once they reach high school (Nelson & Landel, 2007).

Recent studies have found that American students lag behind many of their counterparts around the world in science (Kena et al., 2016). There are several factors at the elementary level that may contribute to lower science scores for American students. Time allotted for science instruction is often reduced to allow for greater emphasis on math and reading instruction (Banilower et al., 2013; Blank, 2013; Bybee, 2013; Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012; National Research Council, 2015; Olson, Tippett, Milford, Ohana, & Clough, 2015). Many elementary teachers are charged with teaching all subjects and are considered generalists rather than specialists (Baldi, Warner-Griffin, Tadler, 2015; Wilson & Kittleson, 2012). Baldi, Warner-Griffin, and Tadler, in their 2015 report for the National Center for Education Statistics, stated that 92% of elementary teachers provide instruction in multiple subjects in self-contained classrooms. Many elementary teachers prefer teaching non-science subjects (Kirst & Flood, 2017; Scott, 2016; Wilson & Kittleson, 2012) and express a sense of inadequacy regarding science content knowledge and instruction (Gillies & Nichols, 2015; Wilson & Kittleson, 2012).

Historical Context

Nearly 60 years ago, the Soviet's successful launch of Sputnik served as a wakeup call to Americans, intensifying Cold War tensions between Soviet Russia and America (Wissehr, Concannon, & Barrow, 2011). The effect of Sputnik in America at that time was to cause a sense of urgency for raising the rigor and expectations of science achievement in schools. Science education in American schools has long been considered essential for national security purposes. Shortly after the Soviet's launch of Sputnik, President Eisenhower, addressing the U.S. Congress, said, "if we are to maintain our position of leadership, we must see to it that today's young people are prepared to contribute the maximum to our future progress" (1958, p. 103). President Eisenhower (1958) went on to present a comprehensive plan to Congress that the Secretary of Health, Education, and Welfare and the Director of the National Science Foundation had helped to develop that included strategies and funding for strengthening science education in America. Since the launch of Sputnik, America went on to win the space race, successfully landing the first man on the moon (Coleman, 2014). The Cold War of the 20th century has ended, but there are new threats today that provide impetus for renewed attention to science education in America. There are increasing concerns about cyber security and the U.S. government's susceptibility to the hacking of foreign entities (Glaser, 2016; Kirsch, 2012; Nocetti, 2015). The threats of plague (Anez, Chancey, Grinev, & Rios, 2012), terrorism (Zehr, 2013), and rising medical costs (Medeiros, Sanchez, & Valdez, 2012) all represent areas of current need where talented and skilled scientists will play essential roles in developing protection and solutions. The good of the country depends on citizens who are scientifically literate (Gibbons, 2003; National Research Council, 2013), and scientific literacy depends on effective elementary science instruction (Barak & Dori, 2011). More recently, Ravanis (2017) cited the importance of effective early childhood science education, underscoring the importance of creating a learning environment in which students would be encouraged to construct new understandings based on their hands-on experiences. President Obama (2009), in his address to the National Academy of Sciences, warned that when other countries out-educate the United States, then they will also out-compete the United States.

With the ongoing debate over how to best reform and improve science education at the elementary level, there can be no debate about the need for improvement. Concern about the low quality and ineffective instruction for science in elementary school has been noted in the research for many years (Abell, 1990). Science instruction has traditionally been allocated less time than other subjects in elementary school or sometimes not included at all (Banilower et al., 2013). While many elementary science curricula have placed an emphasis on a broad array of facts to be learned or memorized, the National Research Council has long contended that there is a need for elementary students to learn more about the practices of scientists (National Research Council, 2007). Many researchers have come to similar conclusions about the need for elementary students to be engaged with the practices of science (American Association for the Advancement of Science, 1993; Rutherford & Ahlgren, 1990). Unfortunately, for many years it has been reported that most elementary teachers are not as confident in the area of science instruction as they are in the other subject areas (Ramey-Gassert, Shroyer, & Staver, 1996). Some have argued that as long as many elementary teachers lack confidence and competence in both science content and in effective science instruction that improvements in science achievement are unlikely (Brobst, Markworth, & Tasker, 2017; Smith & Anderson, 1999).

Over 30 years ago, Ashton (1984) concluded that there is a connection between elementary teachers' lack of comfort with science and science instruction and the effectiveness of their instruction. Since it has been demonstrated that students who fall behind in science during elementary school are not likely to recover from their deficits in middle or high school (Nelson & Landel, 2007), the role of the science specialist may be critical to effective reform for elementary science achievement.

These factors related to elementary science education have, in part, led to a call for elementary science specialists to help improve elementary science instruction (Abell, 1990; Williams, 1990; Hounshell, 1987). While the idea of using elementary science specialists has garnered some support, it has not become a common practice. During the Sputnik era, about half of the elementary schools surveyed were using some type of science specialist, but the popularity of their use eventually began to wane (Century, Rudnick, & Freeman, 2008). Still others, citing budgetary challenges presented by the common use of elementary science specialists, have presented alternatives to science specialists for improving science achievement in elementary schools (Rhoton, Field, & Prather, 1992; Swartz, 1987).

Social Context

Schools are allotted thousands of dollars per student each year to help ensure that they can effectively accomplish their mission to educate children (Jackson, Johnson, & Persico, 2015). According to recent reports, per-pupil spending in America ranges from $7,239 in Tennessee to $21,730 in Alaska (Ajilore, 2013). The average per-pupil spending for elementary and secondary schools in the United States in 2013 was $11,800 (McFarland et al., 2017). While these amounts may seem exorbitant, some claims are made that schools need even more money (Howie & Stevick, 2014; Petty, Fitchett, & O'Connor, 2012). Members of taxing authority boards and school boards have an obligation to their constituents to exercise prudent stewardship of public funds allocated for education. Such prudence requires informed decision making. The use of a science specialist who provides instruction at an elementary school presents added costs for personnel and infrastructure (Levy, Jia, Marco-Bujosa, Gess-Newsome, & Pasquale, 2016). This study will help provide the kind of information needed to justify or to forego such costs.

Beyond the need for budgetary prudence, schools also are charged with providing the best instruction for students to achieve at maximum levels. The previously mentioned threatening issues facing America (e.g. cyber security, epidemic, terrorism) (Glaser, 2016; Kirsch, 2012; Nocetti, 2015) combined with the previously mentioned lagging science scores of American students (Kena et al., 2016) accentuate the importance of science instruction in American classrooms. With a variety of models for science instruction currently being used in American classrooms, and with very little empirical data to support one over the other (Levy, Jia, Marco-Bujosa, Gess-Newsome, & Pasquale, 2016), it is important for schools to know which instructional method yields the best achievement results.

Theoretical Context

This study is grounded in Piaget's (1972) theory of cognitive development. Science achievement is a reference to how well students learn science, and learning is broadly thought of as a cognitive act (Settlage, Butler, Wenner, Smetana, & McCoach, 2015). Learning science requires students to connect new information with old information (Wallace & Coffee, 2016). Research indicates that students learn science better when the instruction is inquiry-based (Smith & Nadelson, 2017). In other words, students who think through what is being perceived by the senses and who are engaged by higher order thinking questions will be better able to construct a mental model. That mental model includes concepts that are assembled by the synthesis of old knowledge with new knowledge. Piaget's theory addresses this process of knowledge construction and describes discrete stages in which it occurs over a person's life (Anghel 2015; Inhelder & Piaget, 1969,1950; Piaget, 1962; Settlage et al., 2015).

Piaget's (1972) theory of cognitive development, which he referred to as genetic epistemology, addresses the origin of thinking (Peterson, 2012). He was intrigued by the processes that occur, and the order in which they occur, that give rise to a child's understanding of the world around him. Piaget addressed the nature of knowledge and how children come to acquire it. He believed that knowledge is acquired through a process of mental operations whereby previous units of knowledge, which Piaget called schemas, must be adjusted to accommodate for new experiences or environmental stimuli (Ghazi & Ullah, 2016; Inhelder & Piaget, 1969,1950; Piaget, 1962).

According to the proponents of inquiry-based science instruction, the cycle of cognitive equilibrium, input of new information, and then either assimilation or accommodation is related to the learning process that should occur in a science class (Crawford, 2007). There has been a move in recent years toward the use of inquiry-based learning (IBL) in K-12 science classrooms, which involves the application of science, often in the forms of engaging, hands-on style learning (National Research Council, 2012; National Research Council, 2013). Studies indicate that students tend to do better when they are able to experience science in ways that allow them to grapple with questions, to hold, to touch, to observe, to record, and to predict (Barak & Dori, 2011; Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Jones, Childers, Stevens, & Whitley, 2012). Students are better able to construct meaning from experiences that engage their senses (Bakken, Thompson, Clark, Johnson, & Dwyer, 2001; Gibbons, 2003). These kinds of experiences help foster cognitive development as well as the construction of new knowledge (Olson & Finson, 2009). If the schemas held by a child are not challenged by new information, then no meaningful learning can occur. This is a very different way of learning science than the mere rote exercises that occur in many elementary classrooms where science is reduced to a seemingly disjointed list of textbook units, chapters, and terms (Diaconu et al., 2012; National Research Council, 2012). Most elementary teachers have had very little training in IBL and have not had the opportunity to learn in an IBL environment (Olson, Tippett, Milford, Ohana, & Clough, 2015; Steinberg, Wyner, Borman, & Salame, 2015). As a result, most elementary teachers, who have been trained as and work as generalists (Baldi, Warner-Griffin, Tadler, 2015; Banilower, 2013; Milford, Ohana, & Clough, 2015; National Research Council, 2014; Olson et al., 2015; Wilson & Kittleson, 2012) are not prepared to engage students in an IBL style of instruction (Dejarnette, 2016). But, Campbell and Chittleborrough (2014) made the case that elementary science specialists would be more likely to provide these kinds of learning experiences for students.

Problem Statement

American students' science achievement scores lag behind many of their age equivalent peers' scores across the world (Kena et al., 2016). A 2015 study called the Program for International Student Assessment (PISA) revealed that 15-year-old students in the United States were outscored in science by their age equivalent counterparts in 24 other countries (OECD, 2016b). Another study, the Trends in International Mathematics and Science Study (TIMSS) in 2015 found that 4th grade students in the Unites States had science scores that lagged behind the 4th graders from nine other countries in the world (Martin, Mullis, Foy, & Hooper, 2016). This disparity in science achievement is alarming considering the many important matters at stake that depend on a scientifically-literate populace (Lederman, Antink, & Bartos, 2014; Nash, 2015).

Scientific literacy is essential for the wellbeing of democracy and for a strong economy (National Academies of Sciences, Engineering, and Medicine, 2016).

To address the need for rigorous, engaging science instruction at the elementary level some schools have turned to the use of science specialists (Campbell & Chittleborough, 2014). According to Banilower et al. (2013), 16% of elementary students are taught science by science specialists in addition to their regular homeroom teacher, while still 10% more are taught science by only a science specialist. That means that 74% of elementary students are being taught science, when they are taught science, by their generalist homeroom teachers.

According to Marco-Bujosa and Levy (2016) elementary schools face challenges in two areas regarding effective science instruction: teachers who have an aversion to science or who feel inadequately prepared to teach science and school-based challenges such as inadequate instructional time, insufficient resources, and unsupportive administrators. While science specialists may offer a solution to the challenges presented by teachers who lack skills and passion for teaching science, Marco-Bujosa and Levy noted that the effect of science specialists may not be enough to overcome the school-based challenges. Marco-Bujosa and Levy’s study found that in the absence of the elementary school principal’s support for science instruction, the overall effectiveness of the school’s science program was limited, regardless of whether the school used science specialists or not.

The use of science specialists in elementary schools affords certain advantages: the science specialist is able to focus solely on preparing for science instruction and on schoolwide science programs; the science specialist typically has greater expertise in the area of science than regular elementary teachers; and the science specialist is often better prepared to provide inquiry-based learning opportunities for students (Marco-Bujosa & Levy, 2016).

According to Brobst, Markworth, Tasker, and Ohana (2017), elementary science specialists hold several advantages over regular classroom teachers in the area of science, including the following:

- Elementary science specialists are more likely to hold science degrees than regular elementary classroom teachers.
- Elementary science specialists report a higher level of confidence in their ability to teach science than regular elementary classroom teachers.
- Elementary science specialists report a higher level of familiarity with science curriculum standards than regular elementary classroom teachers.
- Elementary science specialists report being better prepared to identify students' strengths and weaknesses in science than regular elementary classroom teachers.
- Elementary science specialists report having more time to meet students' learning needs in science than regular elementary classroom teachers.
- Elementary science specialists report having more time for instructional planning than regular elementary classroom teachers.
- Elementary science specialists tend to score higher on science content knowledge than regular elementary classroom teachers.

There are a variety of models used in different elementary schools for elementary science specialists, including the following:

- Some elementary science specialists serve as members of a departmentalized grade level team (Brobst, Markworth, Tasker, & Ohana, 2017). For this model, students rotate to the elementary science specialist's class the same as they rotate to the math teacher's class or to the English teacher's class.

- Some elementary science specialists serve as a pull-out teacher (Brobst, Markworth, Tasker, & Ohana, 2017). For this model, students have scheduled times during which they will go to the science specialist for science instruction in a manner similar to how students are scheduled to go to the music teacher for music class or to the art teacher for art class. For this model, the specialist may be the only person providing science instruction to students, or the specialist may be providing science instruction to students that supplements the science instruction of the regular classroom teacher.
- Some elementary science specialists provide oversight for the science curriculum and instruction, but they do not provide direct instruction to students (O'Day, 2016). In this model, the specialists may serve as a resource person or as a mentor to regular classroom teachers. The specialist may serve as the resident science expert, providing input for instructional planning, for curriculum development, and for the ordering and allocation of science resources and materials.

Other variations in elementary science specialists include their formal training, their prior experience with science instruction, whether they hold science degrees or not, and the length of time that students spend with them for each instructional segment (Brobst, Markworth, Tasker, & Ohana, 2017; Markworth, Brobst, & Parker, 2016; O'Day, 2016). Because of the many variations in the credentials, experience, and roles of elementary science specialists in different schools Brobst, Markworth, Tasker, and Ohana (2017) stated that there has been some confusion in establishing a common definition for elementary science specialists.

This study will focus on the impact of elementary specialists for science. Some may wonder about the role of elementary subject specialists in other subject areas as well. Content specialists are most regularly used in the elementary setting to teach science, technology, the arts and physical education (Levy, Jia, Marco-Bujosa, Gess-Newsome, & Pasquale, 2016). The use of specialists in every subject at the elementary level is known as departmentalization (Parker, Rakes, & Arndt, 2017). Departmentalization may also be referred to as team teaching or as the collaborative specialist model (Gerretson, Bosnick, & Schofield, 2008; Nelson & Landel, 2007). While, according to Parker, Rakes, and Arndt (2017), some elementary schools have moved toward departmentalization, the focus of this study will only be on the impact of specialists in the area of elementary science. There are some factors related to science that seem to suggest that there may be a strong case for the use of elementary specialists for science instruction. The dual nature of science may be cause for the consideration of elementary science specialists. While other subjects tend to be more content-oriented, science includes content as well as the practices of scientists (National Research Council, 2012; National Research Council, 2013). It takes a unique skill set for a teacher to be able to effectively teach students the contents of science while at the same time helping students to develop proficiency in the practices of science. Unfortunately, not only do most elementary teachers express a sense of ineptitude and a lack of preparation for effective science instruction, but many also express an aversion to teaching science (Dejarnette, 2016; Olson, Tippett, Milford, Ohana, & Clough, 2015; Scott, 2016; Kirst & Flood, 2017; Smith, Trygstad, & Banilower, 2016; Steinberg, Wyner, Borman, & Salame, 2015). Also strengthening the case for the use of elementary specialists in the area of science are the expected increases in career opportunities that will require a background in science (National Science Foundation, 2016; Olson & Riordan, 2012). While the forecast is for increases in science-related career fields, American students continue to lag behind their international counterparts in the area of science achievement (Kena et al., 2016). These are the areas of concern that underlie the singular focus of this study on the area of elementary specialists for science.

While science specialists in the elementary setting have been in use for several years, the literature is sparse regarding their impact on science achievement (Levy et al., 2016). The researchers who have examined the role of elementary science specialists have arrived at conflicting results (Marco-Bujosa & Levy, 2016). Brobst, Markworth, Tasker, and Ohana (2017) compared elementary science specialists with regular elementary classroom teachers and concluded that further research is needed to draw more certain conclusions about the quality of instruction provided by elementary science specialists and how elementary teachers should be better prepared to teach science. Some schools and school districts, which are often operating on limited budgets, are investing precious resources to fund the use of elementary science specialists, even though little is known about their effectiveness (Levy et al., 2016). American students are lagging behind in science achievement, but elementary students in Georgia have some of the lowest science scores in America (NAEP, 2015). The problem is that students are struggling in science, but little is known about the effectiveness of using elementary science specialists.

Purpose Statement

The purpose of this causal-comparative study is to determine if there is a statistically significant difference between the science achievement scores of fifth grade students who attend schools where science instruction is delivered by science specialists and those who attend schools where science instruction is delivered by regular classroom teachers, who are considered generalists. The independent variable in this study is the use of a science specialist to deliver science instruction. The dependent variable in this study is the science achievement of the students, where science achievement is defined as the understanding of basic science concepts and the comprehension and application of scientific processes (Carrier, Thomson, Tugurian, & Stevenson, 2014). The students' science achievement scores are measured using the standardized science assessment developed by the state of Georgia called the Georgia Milestones Assessment System. This study adds to current research by measuring the difference between the mean science achievement scores of fifth grade students taught science by specialists and those taught by regular classroom teachers. Archived scores for the GMAS will be used to make this comparison. The participants are fifth grade students from four Georgia schools, two of which use science specialists to deliver science instruction while the other two use regular classroom teachers, or generalists, to deliver science instruction. Schools with similar racial and socioeconomic demographics were invited to participate. Data from two successive years are used to allow for the control of prior science achievement.

Significance of the Study

This study is important as schools and school districts are charged with closing achievement gaps. On a broader scale, there are gaps between the science achievement scores of American students and that of students from other countries around the world; the American students demonstrate lower scores (Kena et al., 2016). Critical decisions are made about how to raise science achievement scores, and in many cases, these decisions are made based more on an anecdotal basis due to the lack of an empirical one (Levy et al., 2016). One such decision is to use science specialists to deliver instruction in elementary schools. While the delivery of science instruction by specialists in elementary schools is a practice that has been used for many years, the literature has little to say about its effect on science achievement (Levy, Jia, Marco-Bujosa, Gess-Newsome, & Pasquale, 2016). In some cases, studies have yielded mixed results regarding the effect of elementary science instruction delivered by a specialist on science achievement scores (Levy et al., 2016). This study adds to the literature to help guide the decision process for educational leaders charged with instructional and curriculum decisions. This study has limited generalizability based on several features of the Georgia schools from which the participants come, including socioeconomics, setting, instructional time allotments, allocation of resources, and school leader areas of focus (Smith, Trygstad, & Banilower, 2016). A positive effect of the use of elementary science specialists on science achievement scores would suggest that elementary schools should seriously consider the use of science specialists to deliver science instruction. Furthermore, such a result would help to justify the costs associated with the use of elementary science specialists (Levy et al., 2016). The results of this study add to the current literature base to help guide decisions related to best science instructional practices and sound budgetary practices.

Research Question

The research question for this study is as follows.

RQ: Is there a statistically significant difference in science achievement scores between elementary students who receive instruction from a science specialist and those who do not as measured by the Georgia Milestones Assessment while controlling for pretest scores?

Definitions

1. *Generalist* – A generalist is a teacher who has had general training in multiple subjects but no extensive training in any one area (Baldi, Warner-Griffin, Tadler, 2015; Gerretson, Bosnick, & Schofield, 2008; Kier & Lee, 2017; National Research Council, 2014; Olson, Tippett, Milford, Ohana, & Clough, 2015).

2. *Inquiry-based science instruction* – Inquiry-based science instruction allows students to learn science content through the application of science processes, which involves practices such as problem solving, critical thinking, observing, questioning, and investigating (Amirshokoohi, 2016; Dejarnette, 2016; Kier & Lee, 2017; Maxwell, Lambeth, & Cox, 2015; National Research Council, 2012; National Research Council 2013).
3. *Science achievement* - Science achievement is a measure of one's understanding of basic scientific concepts and the ability to comprehend and apply scientific processes (Carrier, Thomson, Tugurian, & Stevenson, 2014).
4. *Science instruction* - Science instruction is the process by which a teacher plans for and creates sequential and strategic learning experiences that are intended to improve students' knowledge and understanding related to science (National Research Council, 2007).
5. *Scientific literacy* - Scientific literacy is the condition of having knowledge of science content and command of science practices such that issues related to science faced by individuals or groups may be intelligently discussed, rightly evaluated, and properly decided (Carrier, Thomson, Tugurian, and Stevenson, 2014; Lederman, Antink, & Bartos, 2014; National Academies of Science, Engineering, and Medicine, 2016; OECD, 2016a; Sahin & Deniz, 2016).
6. *Science specialist* - A science specialist is an educator who has had special training in science content and pedagogy and is able to concentrate instruction in only the area of science (Baldi, Warner-Griffin, Tadler, 2015; National Research Council, 2014; Olson, Tippett, Milford, Ohana, & Clough, 2015).

CHAPTER TWO: LITERATURE REVIEW

Overview

While a review of the literature reveals the importance of science education, American students at all levels are scoring behind their counterparts in other developed countries. Preparing students to be attracted to science-related fields of study in college and to science-related careers begins at an early age. To enhance their students' experiences in science, some elementary schools have chosen to use science specialists to provide instruction. Most elementary schools, however, rely on students' homeroom teachers, who are generalists, to teach science along with all of the other subjects. Generalists have general training in multiple subjects, but no extensive training in science. This study is designed to determine whether students receiving science instruction from science specialists tend to score higher on state science assessments than students who receive their science instruction from teachers who are generalists.

Theoretical Framework

Piaget's theory of cognitive development describes the process by which children take in new information (Inhelder & Piaget, 1969,1950; Piaget, 1962). If the newly-acquired information aligns with understandings, or schema, already held by the child then the new information simply reinforces the understandings held by the child. However, if the newly acquired information is in conflict with the understandings, or schema, already held by the child, or if there is no previous understanding about the newly-acquired information, then the child makes cognitive arrangements to account for the newly-acquired information. These cognitive arrangements are what Piaget (1962, 1977) referred to as assimilation. This relates to the process by which students learn in school, including in science class. Students are presented with information or experiences in the science classroom that must then be assimilated into existing schema, or the schema must be reconfigured. If the new information does not fit within the framework of a student's schema then cognitive dissonance occurs, and the schema must be adjusted to resolve the dissonance (Inhelder & Piaget, 1969,1950; Piaget, 1962, 1977).

Research indicates that new information experienced through the stimulation of multiple senses is more likely to impact students than if the information is simply experienced from reading about it or hearing about it (Katai, Toth, & Adorjani, 2014). Even though these kinds of studies have provided strong support for engaging students' senses, many elementary students' experiences in science class are limited to words in books, on handouts, or from their teachers. Students who are given the opportunity to learn science through an inquiry-based approach learn more effectively (Smith & Nadelson, 2017; Varma, 2014).

The four stages of development included in Piaget's (1972) theory are sensorimotor, preoperational, concrete operational, and formal operational. Piaget believed that each stage is marked by certain cognitive abilities. In the sensorimotor stage a child begins to develop a sense of what Piaget (1954) called object permanence, which simply means that a child can understand that an object still exists, even when it cannot be seen. The preoperational stage is marked by a child's ability to begin to use symbols to represent other things (Piaget, 1972). For example, during this stage a child begins talking and is able to associate words with the meanings that they represent. In the concrete operational stage, a child begins to develop a sense of conservation, as is evidenced by the ability to understand that a short row of six coins has the same number of coins as a long, spread out row of six coins (Piaget, 1952a). The formal operational stage, which is the final stage that leads into adulthood, is marked with the ability to think abstractly (Travis,

2016) and to be cognizant of ideas or situations in the mind. In the formal operational stage people become more sophisticated in their reasoning.

The schemas described by Piaget (1952b) represent blocks of related information, or units of knowledge, that a child believes to be true, based on previous experiences and environmental input (Bakken, Thompson, Clark, Johnson, & Dwyer, 2001; Lawson, 2008; Sampson, Grooms, & Enderle, 2013). Piaget described schema as “a cohesive, repeatable action sequence possessing component actions that are tightly interconnected and governed by a core meaning” (p. 7). Wadsworth (2004) likened schemas to index cards, each containing related ideas or understandings, filed in the mind. The knowledge represented by schemas is then called upon by the child to help make sense of input from the world around him.

Piaget described the occurrence of cognitive equilibrium, assimilation, and accommodation in relation to how a child makes sense of experiences or environmental input (Bakken et al., 2001; Inhelder & Piaget, 1969,1950; Lawson, 2008; Piaget, 1962). Cognitive equilibrium occurs when there is no conflict between the schemas held by a child and new experiences or stimuli from the environment. If new experiences or environmental input can be made to align with the schemas held by a child, then the new information is easily assimilated into existing schemas. If, on the other hand, new experiences or environmental input cannot be made to align with a child’s schemas, then a state of cognitive dissonance occurs. Piaget posited that when newly input information is in conflict with what the child previously believed or understood, then a state of disequilibrium occurs (Inhelder & Piaget, 1969,1950; Piaget, 1962). Some reconfiguration of schemas is required so that cognitive equilibrium can be restored. The process by which new information challenges a child’s schema, necessitating a reconfiguration of the schema to restore cognitive equilibrium, is what Piaget referred to as accommodation (Bakken et al., 2001; Inhelder & Piaget, 1969,1950; Lawson, 2008; Piaget, 1962).

Later, developmentalists, and Piaget himself, eventually came to acknowledge that the age boundaries initially associated with Piaget's four stages of cognitive development were subject to variation and that development was a function of both age and experiences (Ewing, Foster, & Whittington, 2011). As such, a child's cognitive operations cannot be fully developed simply with the passage of time as the child gets older, but instead, also depend on the child's experiences (Hinde & Perry, 2007; Olson & Finson, 2009; Sampson et al., 2013). In other words, experiences that engage a child's senses play essential roles both in the child's construction of knowledge as well as in the development of cognitive capacities.

With the reform efforts of recent years one of the goals has been to engage students with inquiry-based learning (IBL), which goes beyond the mere memorization of science facts and includes the application of science and the development of science practices (National Research Council, 2012; National Research Council, 2013). Unfortunately, many elementary teachers have neither been exposed to nor been trained in IBL instructional methods (Olson, Tippett, Milford, Ohana, & Clough, 2015; Steinberg, Wyner, Borman, & Salame, 2015). Most elementary teachers, rather, are trained as generalists and lack the skills to engage students in the practices of IBL (Dejarnette, 2016). Science specialists provide these kinds of experiences for elementary students (Campbell & Chittleborrough, 2014). Science specialists have had more extensive training in science than their generalist colleagues, and they are able to focus singularly on the preparation of effective science instruction (Baldi, Warner-Griffin, Tadler, 2015; National Research Council, 2014; Olson et al., 2015), putting them in a better position to employ IBL instructional strategies with students.

As Piaget's theory suggests, providing students with experiences that help expand their learning capacities, or provoke passage to more advance stages of thinking, is a critical part of a student's educational experience. Because an elementary science specialist is able to focus solely on science instruction there may be a greater likelihood that students will have these kinds of enriching experiences. Generalist teachers, who are charged with teaching all subjects (National Research Council, 2014), and many of which may have a proclivity for non-science subjects, may be less likely to prepare the kinds of experiences that maximize the cognitive development of students.

In addition to provoking the development of more advanced stages of learning, elementary science specialists may also be more likely to provide an inquiry-based learning experience for students. Such inquiry-based learning experiences help present students with new knowledge that may challenge previously held schemata. Many generalist teachers at the elementary level express a sense of inadequacy in their knowledge of science concepts as well as science instruction pedagogy (Diaconu et al., 2012; Gillies & Nichols, 2015; Wilson & Kittleson, 2012). Piaget's (1972) theory highlighted the value of cognitive dissonance for helping learners to acquire new learning.

Related Literature

The Importance of Science Education

The need for effective science instruction at all levels is of paramount importance. The idea of scientific literacy is one that is often discussed as a goal for students and citizens (National Research Council, 2013). The National Academies of Sciences, Engineering, and Medicine (2016) defined scientific literacy as being familiar with the knowledge of science as well as with how knowledge is created by science. The importance of a scientifically literate citizenry cannot be overstated when considering the gravity of the issues facing society. Hofstein, Eilks, and Bybee (2011) asserted that even students who will not eventually pursue degrees or careers in science or engineering will need to be scientifically literate. It is important that students develop sufficient scientific literacy such that they can eventually participate meaningfully in discussions related to the scientific and technological issues impacting their lives and their cultures (Sahin & Deniz, 2016). Effective science instruction is critical to society as today's students will bear the responsibility of making informed decisions as future policy makers. To be prepared for such responsibility, it is essential that today's students develop scientific literacy, including an awareness of how science and technology impact society (Amirshokoohi, 2016; Smith & Nadelson, 2017).

The National Academies of Sciences, Engineering, and Medicine (2016) suggests four reasons why a scientifically literate citizenry is important for society, including the economic rationale, the personal rationale, the democratic rationale, and the cultural rationale. The economic rationale is based on the high number of jobs in modern society that depend on science and technology. The more people there are who have skills related to scientific literacy and technology the more these jobs will be able to be filled, fueling our economy, and helping to bring down unemployment. The personal rationale is based on an individual's need to have a basic understanding of science to be able to make good decisions related to health, product consumption, and lifestyle. Furthermore, scientific literacy will help a person better understand and be able to engage in discussions with healthcare providers. People who are scientifically literate are better positioned to live richer, more satisfying lives. The democratic rationale is based on the premise that many major issues that face our society have a scientific component and they are addressed politically at the ballot box. Such issues include the need for clean water and clean energy, climate change, and disease prevention. The argument has been made that these kinds of issues are best addressed by a scientifically literate citizenry (National Research Council, 2013). Finally, the cultural rationale is based on the belief that the knowledge provided by science and knowing how to practice science brings enlightenment to society. Therefore, a society that is scientifically literate is culturally more advanced.

Recognizing the need to strengthen K-12 science education, many states and districts have adopted the *Next Generation Science Standards* which were developed in 2013 as an extension of the 2012 National Academies of Sciences, Engineering, and Medicine's report, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. The report (NRC, 2012) described the goal of K-12 science education to be students who

> have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (p. 1)

The role of elementary schools to help achieve this goal cannot be overstated. However, the National Research Council (NRC) further reports several factors that have made it difficult for schools to achieve this goal, including: a lack of organization in the layout of science curriculum over multiple years; the way science is often taught as a collection of unrelated facts; a tendency for science instruction to focus on breadth rather than depth of understanding; and the lack of opportunities for students to be challenged with engaging, hands-on opportunities in the science classroom.

Science education is most effective when students are able to see its connections to their own lives, and Bazzul (2015) suggests that when that connection is not made, the results can be destructive. The way that students' lives and the world they live in are shaped is largely impacted by their understanding of science, and thus, the means by which they learn science (Abegglen & Bustillos, 2016).

The importance of effective science instruction extends beyond the need for students to eventually be prepared to understand science processes and the impact of scientific issues on society. The case was made by President Eisenhower (1958) that national security also depends on effective science education. More recently, Dejarnette (2016) stated that there is a great need for scientists and engineers in America. Olson and Riordan (2012) spoke to this need in their report to President Obama, declaring that there was a need for one million more professionals in fields related to science, technology, engineering and math (STEM) over the next decade than the number entering those fields at the current rate. According to the National Science Board's report for the National Science Foundation (2016) the percentage of science and engineering related workers in the U.S. workforce doubled from 2% to 4% from 1960 to 2013. This rising demand for science and engineering skills in the U.S. workforce is in part fueled by the increasing ties of technology to the global economy (National Science Foundation, 2016). With the rise of terrorism and the threats that come with it, our security depends on having bright and talented scientists. Breaches in cybersecurity present an ominously growing threat to our nation (Kirsch, 2012; Pawlowski, 2015). The unorthodox threats presented by terrorists demand a reexamination of our weapons and defense systems (Zehr, 2013). The nation has become very aware of the risks associated with potential nuclear or gas attacks in warfare or terroristic activity. The rise of epidemics in the form of viral diseases presents very real health threats to people everywhere (Anez et al., 2012). Rising healthcare costs (Medeiros, 2013) have taken a prominent position in the minds of citizens and the speeches of policy makers. To mitigate these and other dangers facing the nation it is imperative that students have effective science instruction and that bright, capable students become motivated to pursue degrees and careers in science-related fields.

Scientific Literacy

There is a strong consensus among the research community that scientific literacy must be a goal for all students (NRC, 2013). Scientific literacy is sometimes used synonymously with science literacy and is a concept that has been a part of the literature for about half a century (Lederman, Antink, & Bartos, 2014). Roberts and Bybee (2014) actually distinguished between science literacy and scientific literacy, indicating that science literacy is more closely related to knowledge of science content, while scientific literacy is a broader concept, including not only the knowledge of science content, but also the ability to apply knowledge for the purpose of making evaluations of arguments and in decision making related to issues of science facing individuals or society.

The meaning of scientific literacy has evolved over time to reflect the changing perception of what science is and what science can do (National Academies of Sciences, Engineering, and Medicine, 2016). One of the aims of the *Next Generation Science Standards* (National Research Council, 2013) is for students to develop a level of scientific literacy that would allow them to make intelligent personal decisions and to participate intelligently with discussions related to science and technology. However, even to the present day, there is no single definition for scientific literacy embraced by the entire scientific community.

The National Academies of Science, Engineering, and Medicine (2016) stated that scientific literacy is more than just knowing basic science facts, indicating that scientific literacy involves knowledge of science content as well as a familiarity with the practices of science. Building on that description of scientific literacy, many experts also have said that scientific literacy includes the ability to understand and make informed decisions related to issues faced by individuals and by society (Carrier, Thomson, Tugurian, and Stevenson, 2014; Lederman, Antink, & Bartos, 2014; National Academies of Science, Engineering, and Medicine, 2016; Sahin & Deniz, 2016).

The OECD's (2016a) *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic and Financial Literacy* defined scientific literacy as "the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen" (p. 13). But the OECD definition went further to delineate three competencies that characterize scientific literacy, including the ability to provide scientific explanations for phenomena; the ability to create and assess scientific inquiry; and the ability to extract scientific meaning from data and other evidence (OECD, 2016a). Each of these three competencies represents the kinds of knowledge and skills that need to be taught in K-12 science classes, with the foundation being laid at the elementary level (National Research Council, 2013). Today's elementary students will, as adults, face complex issues for which careful consideration must be given by scientifically-literate policy makers (Carrier, Thomson, Tugurian, & Stevenson, 2014).

In reference to *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012), Duschl (2012) stated that the crosscutting concepts should be thought of as the learning goals for scientific literacy. These crosscutting concepts include those qualities of science that are common between and make links between all subfields of science (National Research Council, 2014). Building on Duschl's proposition, it stands then that elementary students must be exposed to and taught how to recognize the crosscutting concepts, and they must be able to rightly use their knowledge of these concepts to explore and organize science content.

Scientific literacy is more than just what is achieved by an individual; it also includes the state of a community or society, and the collective value of scientific literacy at the community or society level is greater than just the sum of the scientific literacy of the individuals that make up the community or society (National Academies of Sciences, Engineering, and Medicine, 2016). Karisan and Zeidler (2017) emphasized the importance of students developing scientific literacy as it relates to science, technology, and societal issues. The individual scientific literacy of the members of a society collectively contributes to an informed citizenry, which increases the likelihood that science will be rightly applied in the decisions made by the society (Karisan & Zeidler, 2017).

The opportunity to develop scientific literacy is less likely for people who have fewer economic resources (National Academies of Sciences, Engineering, and Medicine, 2016). The lack of access to scientific literacy affects some minority groups more than others, namely students whose first language is not English, Latino students, African-American students, economically disadvantaged students, and students who attend schools where resources are deficient (National Academies of Sciences, Engineering, and Medicine, 2016). This stark reality underscores the urgency of having effective science instruction in every school for every student.

The Complex Nature of Science Pedagogy

Among the most common core subjects, including English, math, social studies, and science (Baldi, Warner-Griffin, Tadler, 2015), science has some unique qualities that make it a bit more complex. Teachers who are charged with teaching students to read have research-based strategies to help students develop the skills required for reading, including phonemic awareness, word recognition, fluency, comprehension, and vocabulary acquisition (Walpole & McKenna, 2017). Regular practice with these skills will result in a student learning to read. Likewise, a math teacher has certain algorithms to teach students how to perform mathematical operations and certain steps to teach students for how to approach word problems, including reading the problem, paraphrasing the problem, visualizing the problem, hypothesizing about the solution, estimating an answer, computing an answer, and checking an answer (Krawec & Montague, 2014). Social studies is largely a study of the stories of humankind from the past that relate to the rise and fall of cultures and civilizations, intended to prepare students to function in a democratic society (Pryor, Pryor, & Kang, 2016).

Science instruction is unique in the sense that science teachers are expected to teach both the content of science as well as the practices employed by scientists (National Academies of Sciences, Engineering, and Medicine, 2016; National Research Council, 2012). The National Research Council (NRC) produced a report in 2012 called *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* that highlighted the complexity of science pedagogy. That NRC report described the tension between learning the concepts and content of science versus learning the practices of science. From the NRC report, Duschl (2012) described what he called the three dimensions around which K-12 science education should be oriented, including practices, crosscutting concepts, and core ideas.

Practices refer to the means by which scientists conduct experiments and assemble new knowledge or understanding. The NRC report (2012) lists these practices:

1. Asking questions (for science) and defining problems (for engineering)

2. Developing and using models

3. Planning and carrying out investigations

4. Analyzing and interpreting data

5. Using mathematics and computational thinking

6. Constructing explanations (for science) and designing solutions (for engineering)

7. Engaging in argument from evidence

8. Obtaining, evaluating, and communicating information. (p. 42)

These practices are not unique to any specific subfield of science. They are the practices that scientists in any scientific field must undertake to achieve the end goals of science (National Research Council, 2012). Science teachers are charged with teaching not only the content of science, but also with teaching these practices to ensure that students better understand the means by which scientific knowledge is assembled and to ensure that students do not come under the false impression that science is simply the study of a vast catalog of facts and concepts.

The second dimension from the NRC report (2012) addresses crosscutting concepts. These are concepts that, like the practices, are not unique to any one subfield of science, but instead help link knowledge between the various subfields of science (National Research Council, 2014). The NRC (2012, 2014) lists seven crosscutting concepts: patterns; cause and effect; scale, proportion, and quantity; systems and systems models; energy and matter; structure and function; and stability and change. Science teachers are charged with not only teaching the content of science, but also with teaching students to use these crosscutting concepts of science to link knowledge between different subfields of science.

Unlike the first two dimensions, the core ideas cited in the final dimension of science instruction from the NRC report (2012) are specific to the various subfields of science. The

NRC report categorizes the core ideas into four subfields: physical science; life science; earth and space science; and engineering, technology, and applications of science. The core ideas associated with these science subfields make up the content where much of science instruction, especially at the elementary level, has traditionally focused (Maxwell, Lambeth, & Cox, 2015). However, for students to develop a deep understanding of science, it is insufficient to reduce science instruction to the mere presentation of scientific facts for students to memorize (Aydeniz, Cihak, Graham, & Retinger, 2012; Steinberg, Wyner, Borman, & Salame, 2015).

The three dimensions of science instruction presented in the NRC report (2012) highlight the complex nature of the task with which science teachers are charged. Science teachers must effectively help students to apply the skills and knowledge of scientists, while linking concepts across science subfields, and to learn science subfield specific content, all at the same time. The NRC report further pointed out that to achieve this daunting task a fresh approach to curricula, instruction, and assessment would be necessary.

The NRC report (2012), *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, served as the foundation for the development of the *Next Generation Science Standards: For States, By States (NGSS)* (National Research Council, 2013). The NGSS was the next step toward a national initiative for the improvement of K-12 science education. The NGSS was developed based on four principles laid out by the NRC's 2012 report, which were a reduction in the quantity of core ideas that should be taught from each science subfield, the integration of the core ideas with the science practices, an emphasis on the crosscutting concepts, and the recognition that the three dimensions of science instruction (practices, crosscutting concepts, and core ideas) would have to be developed over time (Krajcik & Merritt, 2012).

The National Research Council (NRC) placed its endorsement on the NGSS, verifying the alignment of its standards with the aims of *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2013). While the release of the NGSS represented a necessary step toward improved K-12 science instruction, the NRC has acknowledged that there is still much work to be done in the training of teachers for the development of curricula, instruction, and assessment that will align with the goals of *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* and the *Next Generation Science Standards*.

The NGSS helped to define what students need to know by the time they graduate from high school (NRC, 2013). However, the NGSS has fewer disciplinary core ideas (DCI) than what has traditionally been included with K-12 science curricula. The NRC made the point that the reduction in DCIs allows for more attention to be placed on the development of science practices and a greater depth of understanding. This shift in K-12 science education raises the expectations for what K-12 science teachers must be trained and prepared to do in the classroom, especially those teachers who work in the elementary setting, where most are generalists.

Science Achievement in America and Georgia

Unfortunately, many students report that they are bored and uninterested in their science classes (Hofstein et al., 2011; Lazaros, 2012). The way science has traditionally been taught at the elementary, middle, and high school levels has often neglected to capture the attention or to stir the interests of students (National Academies of Sciences, Engineering, and Medicine, 2017). Because in science classrooms the curricula are often presented as a collection of disjointed and unrelated facts (National Research Council, 2012) students often fail to grasp the relevance of science or to be motivated in the area of science (Hofstein et al., 2011). According to Hofstein et al. (2011), those who are in charge of school curricula often emphasize the importance of memorizing facts about science over the importance of learning the practices of science. However, scientific literacy includes, but extends beyond, familiarity with facts and definitions, also encompassing an awareness of scientific processes, or how science is conducted, and also the implications of science related to issues in our society (National Academies of Sciences, Engineering, and Medicine, 2016; Sahin & Deniz, 2016). Educators are remiss to not engage their students at depths beyond the rote level of science facts and definitions. Reducing science instruction to a mere presentation of the vast array of science facts and definitions may be a part of the reason why students lose motivation and have lower science achievement scores.

Recent studies show that American students are outperformed by their counterparts in many other countries (Maxwell, Lambeth, & Cox, 2015; Schmitt, 2013). According to the 2015 Program for International Student Assessment (PISA), students in 24 education systems around the world earned higher scores in science than American students (OECD, 2016b). Schmitt (2013) reported that students in Georgia ranked 46th for on time graduation rates and that the percentage of Georgia students considered to be proficient in science was below the national average. In the most recent National Assessment of Educational Progress (NAEP), also known as the Nation's Report Card, Georgia fourth graders improved their national ranking for science achievement from the 2009 assessment to rise from the 9th lowest to tie Rhode Island for the 13th lowest place among all the other states and the District of Columbia (NAEP, 2015). The NAEP science scale ranges from 0 – 300. Georgia fourth grade students improved their score from 2009 to 2015 by eight points, rising from 144 to 152. In the same time period, the national average score on the NAEP science test improved from 149 to 153. Georgia, then, is scoring very close to the national average on the NAEP science test. Unfortunately, NAEP (2015) reported that this is still beneath the score considered to be proficient. While Georgia appears to be moving in the right direction, it has just barely scored out of the lower quartile of states in the area of science achievement. According to Maxwell, Lambeth and Cox (2015), students in Georgia have in recent years demonstrated slight improvements in science achievement, but a more prevalent use of inquiry-based learning (IBL) is necessary to foster more significant improvements. In their report for the National Center for Education Statistics, McFarland et al. (2017) stated that in 2015 only 38% of the fourth graders in the U.S. earned proficient scores in science.

Elementary Science Education

As the research has shown, effective science instruction is of paramount importance for a variety of reasons. It is essential that students be equipped with a level of scientific literacy that will enable them to understand and participate with discourse related to science and society. Furthermore, the experiences provided for students in science classrooms should serve to stimulate their interests in science and to help motivate the pursuit of science degrees and careers. Elementary science education plays a critical role in the larger scheme of K-12 science education. Kier and Lee (2017) stated that the elementary classroom is where many students have their first opportunity to develop an understanding of how scientists work and of how scientific knowledge is acquired. Kier and Lee further asserted that the elementary classroom provides a foundation from which students may develop an interest in science that may endure for the rest of their lives. Steinberg, Wyner, Borman, and Salame (2015) expressed similar sentiments regarding the importance of elementary science education saying that the early years are when the foundation is laid which is required for future science learning.

Students who have effective, engaging science instruction in elementary grades are more likely to develop a sense of self-efficacy in science and to experience success in more advanced science courses in high school and beyond (Dejarnette, 2016; Schmitt, 2013). The need for children to develop an early sense of confidence with science is accentuated by the expectancy value model of motivation, which says that children who develop a sense of competence in an area will be more likely to be motivated to do well in that area (Simpkins, Fredricks, & Eccles, 2012). To achieve these goals, a proper science foundation must be laid for students at the elementary level. Instruction that engages students at the elementary level with scientific concepts may increase the likelihood that those students will have greater interest in science when they reach high school or even eventually enter a science-related career field (Lazaros, 2012; Schmitt, 2013). Giving students exposure to appropriate science instruction at the elementary level can help prepare them for the rigors of middle and high school science courses and eventual entry to STEM degree programs in college (Dejarnette, 2016).

Bearing in mind the importance of effective science instruction at the elementary level, it is important to consider what constitutes effective instruction. With high quality, engaging instruction, students are more likely to develop a sustained interest in science (Campbell & Chittleborough, 2014; McGrew, 2012; Smith et al., 2016). There is a push for K-12 science reform to produce higher achievement for U.S. students by enhancing instructional practices in the science classroom (Keeley, 2005; National Research Council, 2007; National Research Council, 2012; National Research Council 2013). Such enhancements would include strategies that go beyond the mere presentation of, memorization of, and recitation of science content (Smith & Nadelson, 2017). These kinds of enhancements are aligned with what is commonly referred to as inquiry-based learning (IBL) and include such practices as measuring, observing, collecting data, investigating, asking questions, and solving problems (Amirshokoohi, 2016; Dejarnette, 2016; Kier & Lee, 2017; Maxwell, Lambeth & Cox, 2015; National Research Council, 2012; National Research Council 2013). An inquiry-based approach to science instruction provides students with an opportunity for hands-on learning and for grappling with deeper questions related to their observations and experiences. Such authentic learning experiences are said to be the most likely to engage students and to help them retain what they learn (Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Harman, Cokelez, Dal, & Alper, 2016). This kind of authentic science learning includes the collection and interpretation of data (Jones et al., 2012), which is far different than the mere absorption and recitation of science facts and definitions. Qarareh (2016) stated that effective science teaching should help "students to acquire various scientific thinking skills such as: observation, classification, measurement, conclusion, forecasting, judging, induction, inference, interpretation of data, control of variables, etc." (p. 182). These approaches to science instruction align with the recommendations of the 2012 report, *A Framework for K-12 Science Education* (National Academies of Sciences, Engineering, and Medicine, 2017). The Next Generation Science Standards (NGSS) were developed from the 2012 report and have served as a guide for many states and local districts seeking to revamp their K-12 science instruction.

Research suggests that these are the features of effective science instruction and that they should be a part of elementary science classes. Students who learn only about the content of science and are not exposed to the process of science through inquiry style instruction are likely to become bored with science and lose interest. Unfortunately, many elementary science teachers are unfamiliar with or uncomfortable with a less scripted, inquiry style of instruction (Dejarnette, 2016). A science specialist at the elementary level is more likely to be familiar with and have the time and expertise to plan for the inquiry style learning that engages students with science processes (Levy, Jia, Marco-Bujosa, Gess-Newsome, & Pasquale, 2016).

The National Research Council (2012) makes a connection between inferior elementary science instruction, the achievement gap between some minority groups and their counterparts, and a disproportional under-representation of members of those minority groups represented in science-related programs of study and careers. There is an achievement gap in most subjects, including science, with members of some minority groups scoring significantly lower than their counterparts. This achievement gap, at least in part, is believed to possibly be related to instructional techniques that are less engaging for members of minority groups. Students who are less interested in their science classes are then less likely to be attracted to more advanced science courses in high school and beyond. Members of minority groups for whom traditional science instruction fails to cultivate interest then not only tend to achieve at a lower level but are also less likely to study and enter science related career fields, widening the achievement gap from the classroom into the workplace.

The literature also addresses the cost of science instruction. There is an increasing pressure for schools to raise student achievement levels with limited and in some cases reduced per-pupil budgets (Guthrie & Ettema, 2012). Compared to the cost of other subjects, the cost of quality science instruction tends to be higher as it requires certain supplies and equipment to provide students with meaningful science practice and learning (National Research Council, 2015). Levy et al. (2016) found that when comparing elementary schools with successful science programs that those which did not use science specialists were able to save costs and still have similar results as those which did use science specialists.

Science Education Reform and Inquiry-based Learning

The efforts of the National Research Council (NRC) in the publishing of *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (2012) and the *Next Generation Science Standards (NGSS)* (2013) were driven in part by the realization that K-12 science instruction in America has had a tendency to focus on a broad range of content and the memorization of discrete, seemingly disconnected ideas (Harris et al., 2015). The NRC's reports have served as the foundation for K-12 science instruction reform. The reform efforts have been oriented around the need for students to be more engaged with the application of science processes rather than the mere reception and recitation of science facts (Smith & Nadelson, 2017).

The style of instruction and learning that supports the aims of the NGSS is often referred to as inquiry-based learning (IBL) (National Research Council, 2013). IBL requires that students learn content through the application of science processes (Amirshokoohi, 2016). These processes are delineated in the NRC's eight practices (National Research Council, 2012). Several authors have made the argument that students who receive science instruction in a traditional manner, with no opportunity for IBL, are not likely to learn science content beyond a superficial level (Aydeniz, Cihak, Graham, & Retinger, 2012; Maxwell, Lambeth, & Cox, 2015; National Research Council, 2012; National Research Council, 2013).

A distinction is often made in the literature between the characteristics of inquiry-based learning (IBL) and traditional approaches to science instruction. Traditional K-12 science instruction typically is teacher-directed and involves lectures, demonstrations, and the memorization of scientific facts (Amirshokoohi, 2016; Aydeniz, Cihak, Graham, & Retinger, 2012; Kier & Lee, 2017). In contrast to the traditional methods of K-12 science instruction, IBL involves more hands-on learning opportunities, problem solving, critical thinking, observing, questioning, and investigating (Amirshokoohi, 2016; Dejarnette, 2016; Kier & Lee, 2017; Maxwell, Lambeth & Cox, 2015; National Research Council, 2012; National Research Council 2013). Aydeniz et al. explained that IBL involves real life problems and the use of scientific reasoning. IBL, according to Dejarnette, is more student-directed and allows students to engage in the construction of their own knowledge. The National Research Council's (NRC) *A Framework for K-12 Science Instruction: Practices, Crosscutting Concepts, and Core Ideas* (2012) touted the value of IBL for having students simultaneously apply the skills of science while also engaging the content of science. The NRC's report also explained that a part of IBL includes learning to manipulate scientific variables while conducting investigations.

While the intent of the National Research Council's (NRC) *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (2012) and its *Next Generation Science Standards* (2013) seems to be a shift toward inquiry-based learning (IBL), such a shift requires a commensurate change in pre-service and in-service teacher development (Dejarnette, 2016; Maxwell, Lambeth, & Cox, 2015). Amirshokoohi (2016) said pre-service teachers should be trained in how to conduct inquiry activities. Elementary teachers, who often have less confidence and less comfort in the area of science instruction (Kirst & Flood, 2017; Scott, 2016; Wilson & Kittleson, 2012), may need extra support for knowing how to effectively plan for the kinds of hands-on learning activities characteristic of IBL (Dejarnette, 2016). Many elementary teachers have a deficit in their knowledge of science content and of science practices (Steinberg, Wyner, Borman, & Salame, 2015). Most college and university teacher preparation programs for elementary teachers have minimal requirements in science content courses and even less preparation to help teachers know how to teach science practices (Olson, Tippett, Milford, Ohana, & Clough, 2015). Dejarnette (2016) further explained that there is a correlation between elementary teachers' comfort level with inquiry-based learning (IBL) and their students' science achievement. This correlation holds true as well for elementary teachers' level of formal science training. Studies have shown that teachers who take (or took) IBL science courses are more likely to employ IBL techniques with their own students in their own classrooms (Kier & Lee, 2017; Steinberg, Wyner, Borman, & Salame, 2015). Professional development for current teachers and appropriate training for pre-service teachers will clearly be in order to enhance the capacity of science teachers so they will be equipped to facilitate the kinds of reforms the NRC seeks to implement.

Improving Science Instruction

With the science instruction reform initiatives promoted by the National Research Council's *A Framework for K-12 Science Instruction: Practices, Crosscutting Concepts, and Core Ideas* (2012) and *Next Generation Science Standards (NGSS)* (2013), schools are employing a variety of innovative strategies to help promote improved science instruction.

Critical discourse (conversation and argumentation). Authors have described the value of critical discourse, including conversation and argumentation, to help students to strengthen their understandings of science and engineering concepts (Colley & Windschitl, 2016; Duschl, 2012; Huff and Bybee, 2013). Students who engage in rich conversation about science concepts and who become accustomed to using evidence to argue for or against points of conversation are likely to discover new ideas and to expand their understanding of science concepts (Colley & Windschitl, 2016).

Strong science teacher leadership. One study focused on the value of strong science teacher leadership for improving science achievement and for closing the achievement gap within a school (Wenner, 2017). Wenner (2017) concluded that strong teacher leadership in the area of science is essential for helping other teachers to rightly interpret science learning standards and to align them with the Next Generation Science Standards (NGSS). Additionally, strong science teacher leaders help to determine professional development needs and to lead in professional development, they help model lessons for other teachers, and they serve as a resource from which other teachers may glean ideas related to science content (Wenner, 2017). Much of Wenner's description of strong science teacher leaders may also be applicable to elementary science specialists, who focus only on the subject of science and who may also help provide guidance for the generalists in the school.

Helping students to see the relevance of science. Amirshokoohi (2016) described the benefits of addressing issues related to science, technology and society, referred to as STS issues. These STS issues include such topics as stem cell research, global warming, nuclear waste disposal, genetic engineering, landfills, global energy demands, and the use of growth hormones in the meat industry (Amirshokoohi, 2016). Incorporating STS issues with science instruction helps students to better understand how science, technology, and society are related and how each can impact the others. Furthermore, Amirshokoohi contended that students who develop an awareness of the connections between these issues will be better prepared as future policy makers to make informed decisions. Most elementary teachers are not introduced to STS issues in their pre-service training and therefore lack the knowledge and skills to develop STS proficiency with their own students (Amirshokoohi, 2016). Scott (2016) addressed similar benefits to having students involved in what she called citizen science by engaging them with projects in their communities. Not only does this increase the likelihood of students gaining a deeper understanding of science concepts, but it also helps to cultivate interests for students who may otherwise have not thought of science as something that related to them or was of interest to them (Scott, 2016). Dalvi and Wendell (2015) documented further benefits from students working on projects relevant to their lives, including the application of science concepts to address problems as well as the development of problem-solving skills. These kinds of benefits would not be as likely for students receiving traditional science instruction, only listening to lectures, and memorizing facts.

The use of models. The literature has documented the importance of teaching students to use models to enhance their understanding of science concepts (Krajcik & Merritt, 2012; VanLehn, 2016). Students' use of models would include the creation, evaluation, and revision of models in the science classroom (Krajcik & Merritt, 2012). This is also one of the eight science practices that the National Research Council (2012) has suggested that all students should learn to apply in all science classes. Models help students to visualize and understand concepts or observed phenomena. They may simplify, but at the same time accurately represent how a system or a process works. According to Krajcik and Merritt (2012), models may include "diagrams, three dimensional physical structures, computer simulations, mathematical formulations, and analogies" (p. 6). Jensen (2012) observed that students in her study were able to see evidence of what they had learned and how their thinking had changed over time by comparing their initial models to their final models. O'Day (2016) explained how models may be used to generate valuable experiences for students in the science classroom, including considering what about models is different than the reality that they represent; using models to make predictions; using models to represent the relation of elapsed time with processes being studied; and to identify limitations of models. The process of creating models, evaluating the precision with which they can predict or match observed data, and then revising the models so that they more accurately match observations taps a higher level of thinking for students (Krajcik & Merritt, 2012).

Emphasis on doing science, not just knowing science. It is important for science instruction to go beyond mere knowing so that it also includes the doing of science (Dalvi & Wendell, 2015; Duschl, 2012; Krajecik & Merritt, 2012). To this end, Duschl (2012) discussed the value of the crosscutting concepts from the National Research Council's *A Framework for K-12 Science Instruction: Practices, Crosscutting Concepts, and Core Ideas* (2012) for K-12 science instruction. The seven crosscutting concepts from the NRC report (2012) describe themes that are common across all subfields of science and Duschl made the case that these help to define the kinds of things students should be doing in classrooms. Amirshokoohi (2016) made reference to the value of engaging students with hands-on learning opportunities. When students are involved in doing science, they are afforded the opportunity to construct knowledge in a way that helps them learn at a deeper level (Dejarnette, 2016).

Generalists and Specialists

With a research-based description of what effective instruction should look like in the elementary science class, it is also important to consider who is best qualified to deliver that kind of instruction. Most elementary teachers are charged with teaching all subjects to their classes (Banilower, 2013; Olson, Tippett, Milford, Ohana, & Clough, 2015), with a heavy emphasis on teaching language arts (reading and writing) and math (Blank, 2013). Banilower (2013) further reported that only 20% of students in grades K-2 receive science instruction on all or most days and 35% of students in grades 3-5. There are likely several reasons for the abbreviated science instruction time at the elementary level, one of which would likely be that over half of new elementary teachers feel they are unprepared to teach science, while over 80% of them report being comfortable with teaching reading (Kirst & Flood, 2017). Most elementary teachers feel the least qualified to teach science, more so than any of the other subjects they teach (Diaconu et al., 2012; Gillies & Nichols, 2015; Wilson & Kittleson, 2012). Because elementary teachers are often charged with teaching all subjects, they tend to be generalists rather than specialists when it comes to science (Baldi, Warner-Griffin, Tadler, 2015; Kier & Lee, 2017; National Research Council, 2014; Olson et al., 2015; Wilson & Kittleson, 2012;). That is to say that they may have a shallow knowledge base of both science content as well as best instructional practices related to science (Diaconu et al., 2012).

Studies have revealed several factors that negatively impact science instruction at the elementary level. Elementary generalist teachers' content knowledge in the area of science is often not as strong as their knowledge in subjects such as reading or even math (Kier & Lee, 2017; Kirst & Flood, 2017; Scott, 2016). Adamson, Santau, and Lee (2013) contended in their study that elementary teachers may not be aware that effective science instruction should go beyond the mere transmission of science content and should include helping students learn to conduct science through inquiry and investigation. Many elementary science teachers express a concern for the lack of time, resources, materials, and professional development necessary for science instruction (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012; Smith & Nadelson, 2017). There are many demands on the daily elementary schedule, including recess, activity classes, and heavy emphasis on literacy and math, often leaving a shortened time for science instruction (Baldi, Warner-Griffin, Tadler, 2015; Banilower et al., 2013; Maxwell, Lambeth, & Cox, 2015; Olson, Tippett, Milford, Ohana, & Clough, 2015). Banilower et al. further reported that 61% of elementary teachers in their study described a lack of support for science instruction.

The science specialist model of elementary science instruction has been employed by some schools (Levy et al., 2016). A specialist is someone with greater knowledge of science, an understanding of science instruction pedagogy, and the opportunity to focus on just science, unlike the generalist classroom teachers who prepare instruction for multiple subjects (National Research Council, 2014). Some authors (Olson, Tippett, Milford, Ohana, & Clough, 2015) attribute the use of elementary science specialists in some schools in part to the challenges often inherent in the elementary setting, including lack of self-efficacy for science instruction expressed by many elementary teachers (Kirst & Flood, 2017; Scott, 2016; Wilson & Kittleson, 2012); the tendency of many elementary schools to reduce time allotted for science instruction to better support literacy and math instruction (Baldi, Warner-Griffin, Tadler, 2015; Banilower et al., 2013; Maxwell, Lambeth, & Cox, 2015; Olson et al., 2015); and the lack of science resources in many elementary schools (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012; Smith & Nadelson, 2017).

Marco-Bujosa and Levy (2016) made a distinction between barriers in elementary science instruction that were personal and those that were school based. Personal barriers are those that arise from teachers' personal aversion for science or their personal lack of self-efficacy for science instruction. School-based barriers were classified in one of four categories: leadership, resources, culture, and external environment, and included such things as a culture that fails to place a priority on science instruction or from a lack of resources or lack of professional development to foster robust science instruction. In their study, Marco-Bujosa and Levy raised the question about whether elementary science specialists would be able to overcome both the personal barriers as well as the school-based barriers. The leadership role of the principal plays a critical role in the success of the science program at elementary schools

(Carrier, Thomson, Tugurian, & Stevenson, 2014). Marco-Bujosa and Levy (2016) found that the principal's role in creating a culture of support for science was so important that in the absence of strong support from the principal, elementary science specialists were unable to overcome the school-based barriers.

The role of the elementary science specialist may vary among schools, districts, or states (Olson, Tippett, Milford, Ohana, & Clough, 2015). Olson et al. (2015) pointed out that while more schools are looking to use elementary science specialists, such use presents certain challenges. Since the role of a science specialist is not one with clear definition, schools must consider what qualifications a teacher should have to serve as an elementary science specialist. Further challenges include how to contend with the strong traditional model of one teacher teaching students in elementary schools, how to accommodate elementary students' time with the science specialist in already complex instructional schedules, and how to facilitate the collaboration of a science specialist with several teachers across the school (Olson et al., 2015).

Summary

The theoretical framework on which this study is based is Piaget's (1972) theory of cognitive development, in which the stages of cognitive development are described as well as the process by which new information is taken in and assimilated based on schema held in the mind of the learner. This theory relates to this study in that learning is a cognitive process, and effective instruction is designed to fit properly with the developmental stages of learners.

The importance of effective science instruction is brought into focus by the research. Concerns related to national security have been shown to have direct lines to the need for a strongly scientific citizenry. It is essential for the nation's populace to understand and to participate in national discourse related to science matters. This level of scientific literacy is not achieved through rote science instruction but rather through the engagement of students with experiences that prompt deep level thinking and grappling with questions related to what students handle, feel, observe, analyze, and discuss. Providing elementary students with these kinds of rich science experiences increases the likelihood that they will be interested in science and motivated to pursue advanced science studies and possibly a career in a science-related field.

This study examines the use of science specialists to deliver science instruction to elementary students in contrast with elementary teachers who are subject generalists who deliver science instruction to elementary students. The research is strong in favor of inquiry-based, authentic-style science instruction (Smith & Nadelson, 2017). Nonetheless, many elementary teachers, who are generalists, express high levels of discomfort and lack of preparation to teach science. Furthermore, the amount of time allotted to science instruction in many instances has been decreased to make allowances for extended blocks of literacy and math instruction (Baldi, Warner-Griffin, & Tadler, 2015; Maxwell, Lambeth, & Cox, 2015; Olson, Tippett, Milford, Ohana, & Clough, 2015). These and other factors have led to the current condition of science achievement, for which American students are falling behind many of their counterparts around the world. And, in Georgia, many students lag behind their counterparts in the rest of the country.

With an awareness of what research indicates is the most effective delivery style for science instruction, this study will consider whether the science specialist may be more likely to administer effective science instruction and therefore promote higher science achievement for students. While science specialists have been used in some elementary schools for several years, the research on whether there are significant differences between science achievement scores for students is inconclusive (Kier & Lee, 2017; Olson, Tippett, Milford, Ohana, & Clough, 2015).

CHAPTER THREE: METHODS

Overview

This study examined the effect of using science specialists to deliver science instruction in Georgia elementary schools by comparing the mean science achievement scores for fifth grade students who received their science instruction from science specialists (elementary teachers who only teach science) to that of fifth grade students who received their science instruction from teachers who are generalists (elementary teachers who teach all subjects). In this chapter the study design is presented followed by the research question and hypothesis. A description of the participants and setting is included. The instrument used to measure science achievement is explained along with the procedures followed by the researcher. This chapter concludes with a description of the data analysis from which results were drawn.

Design

The purpose of this causal-comparative study was to compare the science achievement scores of fifth grade students who received their science instruction from science specialists to those who did not receive their science instruction from science specialists. For this study a science specialist refers to a teacher who has had some special training in science content and pedagogy and who teaches only science (Baldi, Warner-Griffin, Tadler, 2015; National Research Council, 2014; Olson, Tippett, Milford, Ohana, & Clough, 2015). The causal-comparative research design is appropriate for this study because the researcher collected test scores from archived data and made comparisons between group means in a study for which selecting participants in a purely random fashion was not feasible. According to Gall, Gall, and Borg (2007) the causal-comparative research design is appropriate for comparing two groups to look for a possible cause-and-effect relationship between the independent variable and the dependent variable. The independent variable in this study was the use of a science specialist to deliver science instruction to elementary students. The dependent variable in this study was the science achievement of the students. For this study science achievement was defined as the understanding of basic science concepts and the comprehension and application of scientific processes (Carrier, Thomson, Tugurian, & Stevenson, 2014). Gall et al. further described the causal-comparative design as having an independent variable that is measured in nominal categories. The independent variable for this study was measured in categories based on the kind of science instructor students had. The two categories of science teachers were specialists (teachers who taught only science) and generalists (teachers who taught multiple subjects).

Research Question

RQ: Is there a statistically significant difference in science achievement scores between elementary students who receive instruction from a science specialist and those who do not as measured by the Georgia Milestones Assessment while controlling for pretest scores?

Hypothesis

The null hypothesis for this study is:

H_0: There is no statistically significant difference in science achievement scores between elementary students who receive instruction from a science specialist and those who do not as measured by the Georgia Milestones Assessment while controlling for pretest scores.

Participants and Setting

The participants for this study are fifth grade students from four different public schools in rural, north Georgia. All fifth grade students who do not have Individual Education Plans (IEPs) are used from each school. An IEP is a plan, required by the federal Individuals with Disabilities Education Act (IDEA), that, among other things, describes the services and accommodations that must be provided for students with disabilities. Students with IEPs may have lower science scores because of their disabilities rather than because they received science instruction from a science specialist or a generalist. The reason students with IEPs were removed from the study was to eliminate the possibility of the study's results being skewed as a result of disparities between the schools' numbers of students with disabilities. According to Lam, Doverspike, Zhao, Zhe, and Menzemer (2009), many students with disabilities have trouble accessing knowledge and expressing what they have learned.

The schools in the study from which the student participants come were selected for convenience and for their similarities. Two of the participating schools use science specialists to deliver science instruction, while the other two schools do not use science specialists. The schools where science specialists are used to deliver instruction were checked to compare the science instruction delivery (refer to Table 1). To verify the comparability in how science instruction was delivered at the schools that used science specialists, the principals were asked to complete a simple survey (see Appendix B).

Table 1

Comparability of Science Instruction Delivery for Schools that Use Science Specialists

	School C	School D
Length of Science Instruction Each Class	75 Minutes	55 Minutes
Regularity of Science Instruction	One Class Per Day	Five Classes Per Month
Location Where Science Instruction Occurs	Separate Science Classroom	Separate Science Classroom
Science Specialist Serves as Resource to Collaborate with Other Teachers	Yes	Yes
Additional Science Instruction Delivered by Teacher(s) Other than the Science Specialist	No	Yes

The researcher selected schools with similar racial and socioeconomic demographics. The researcher used demographic data, including both racial and socioeconomic information, documented publicly by the Georgia Governor's Office of Student Achievement (GOSA) to ensure the comparability of the demographic makeup of participating schools. The researcher used scores from two successive years of the GMAS science assessment to allow for the control of prior achievement. The researcher removed students who were new to the school during the two-year period from which the GMAS scores were collected from the study. The fifth grade enrollment at each of the participating schools determined the number of participants in the study. The study required at least 66 participants to ensure a medium effect size with a statistical power of 0.7 and an alpha level of 0.05 (Gall, Gall, & Borg, 2007). The number of participants in this study exceeded that threshold, with 121 students participating from the schools where science specialists teach science and 161 students participating from the schools where generalists teach science. The distinction between the two groups of classes is that one group was taught science by science specialists while the other group was taught science by generalists. Table 2 summarizes the racial/ethnic status of the students in each school and each group of schools. Table 2 summarizes the economic status of the students in each school and each group of schools. Table 4 summarizes the gender of the students in each school and each group of schools:

Table 2

Student Race/Ethnicity Summary for Study Subjects from Participating Schools

Demographic Description	Schools Where Specialists Teach Science			Schools Where Generalists Teach Science		
	School A	School B	Total	School C	School D	Total
African American	0	0	0	1	0	1
White	49	65	114	81	65	146
Hispanic	2	4	6	5	6	11
Asian	0	0	0	0	1	1
Mixed	1	0	1	1	1	2
Other	0	0	0	0	0	0
Total	52	69	121	88	73	161

Table 3

Student Gender Summary for Study Subjects from Participating Schools

Gender Description	Schools Where Specialists Teach Science			Schools Where Generalists Teach Science		
	School A	School B	Total	School C	School D	Total
Male	23	36	59	47	30	77
Female	29	33	62	41	43	84
Total	52	69	121	88	73	161

Table 4

Student Economic Status Summary for Study Subjects from Participating Schools

Economically Disadvantaged	Schools Where Specialists Teach Science			Schools Where Generalists Teach Science		
	School A	School B	Total	School C	School D	Total
Yes	37	44	81	45	45	90
No	15	25	40	43	28	71
Total	52	69	121	88	73	161

Instrumentation

The fifth grade Georgia Milestones Assessment System (GMAS) end-of-grade science test was used to assess science achievement for this study's participants. The GMAS was developed by the Georgia Department of Education (GaDOE) to assess student achievement related to the state's curriculum standards at the end of grades three through eight and at the end of high school courses (Georgia Department of Education, 2017a). The GaDOE described the development of the GMAS as involving the input of Georgia educators throughout the entire process (Georgia Department of Education, 2017a). The Georgia Department of Education (2016b) further explained the work of the Georgia Technical Advisory Committee (TAC) to ensure the technical quality of the GMAS, including validity and reliability standards that meet the Standards for Educational and Psychological Testing established by the American Educational Research Association, the American Psychological Association, and the National Council on Measurement in Education. Since the GMAS was only implemented in Georgia in the spring of 2015, there have not been many peer-reviewed studies that used the GMAS. One peer-reviewed study that relied on GMAS scores was that of Chisolm (2016), who studied, among other things, the relationship between parents' access to school-based parent resource centers (PRCs) and student academic achievement. Chisolm found that there was no significant relationship between students' achievement in English language arts (ELA) and math and their parents' use of school-based PRCs. Hise (2016) conducted a study comparing the GMAS with the state's previous End-of-Course Tests (EOCT) for high school students and found that students tended to score higher on the former test. While the GMAS was only implemented in the spring of 2015, it is used in Georgia to assess students' growth as well as for the evaluation of teachers' instructional effectiveness (Alvermann & Jackson, 2016).

The fifth grade GMAS science test comprises 75 selected response (multiple choice) items. Students take the test in two sessions and are allowed up to 70 minutes to complete each session. The test generates both a scaled score as well as an achievement level designation for each student. The scaled scores range from 160 to 780. The four achievement level designations include beginning (Level 1), developing (Level 2), proficient (Level 3), and distinguished (Level 4). There are cutoff scaled scores that determine which achievement level a student earns. Students with scaled scores between 160-474 are at Level 1; students with scaled scores between 475-524 are at Level 2; students with scaled scores between 525-594 are at Level 3; and, students with scaled scores between 595-780 are at Level 4.

The test includes both criterion-referenced items as well as norm-referenced items. The criterion referenced items are aligned with Georgia's learning standards for fifth grade. The norm referenced items are referenced to national norms, allowing comparisons to be made between a student's performance and other students across the nation. Only the criterion referenced items contribute to the scaled scores and the achievement levels.

Of the 75 test items, 45 of them are criterion referenced, 20 of them are norm referenced, and 10 of them are field test items, meaning that they do not count toward the scaled scores, the achievement levels, nor the national rankings. The field test items are on the test to allow test developers the opportunity to prepare questions for future iterations of the test.

The questions on the test represent three science domains, including Earth science, physical science, and life science. The weight, in terms of the number of questions on the test for each of these domains, is 30%, 30%, and 40%, respectively.

The GMAS assesses both understanding of basic science concepts as well as proficiency with science practices based on the Georgia Standards of Excellence (GSE) curriculum guide for the state of Georgia (Georgia Department of Education, 2016a, 2017b). The Georgia Department of Education (2016a, 2017b) asserted that the concepts and practices assessed by the GMAS are aligned with the Benchmarks for Science Literacy published by the American Association for the Advancement of Science in 1993.

The GaDOE posts reliability measures related to each subject and grade level for its GMAS end-of-grade tests based on Cronbach's (1951) alpha reliability coefficient. For the 2015-2016 administration of the fourth and fifth grade GMAS science tests, the GaDOE claimed median Cronbach's alpha reliability coefficients of 00.91 and 00.90 respectively (Georgia Department of Education, 2016b). For the 2016-2017 administration of the fifth grade GMAS science test, the GaDOE claimed an average Cronbach's alpha reliability coefficient of 00.90 (Georgia Department of Education, 2017c). The GaDOE (2017c) claimed that the GMAS tests are valid, citing multiple processes followed in the development of the assessments to ensure their validity, including: (a) the collaboration of professional educators to ensure an alignment of the assessments with the state's learning standards; (b) the use of professional assessment specialists to write the test questions; (c) the use of field testing prospective test questions; (d) committee reviews of the test questions to avoid potential biases that may present unfair disadvantages to certain student groups; (e) ensuring statistical and content weight consistency among different versions of the assessments; and (f) the conversion of raw scores to equitable scaled scores. The researcher did not need permission to use the instrument as the schools from which the data came had already administered the GMAS. Instead, the researcher only needed to access archived data for the schools. The researcher accessed that data from the Georgia Department of Education (GaDOE).

Procedures

The study proposal was submitted to the Liberty University Institutional Review Board (IRB) for approval (see Appendix A). After IRB approval was granted, the researcher called on schools to inquire about what kinds of teachers, specialists or generalists, deliver science instruction to determine schools that would be suitable for this study. School principals were asked to complete a questionnaire (see Appendix B) to confirm the means by which science instruction is delivered to students and to determine what schools would be suitable for this study. Among other things, the survey asked about the length of time students spent in science class and how many times they were taught science during a typical week. As has already been established, an elementary science specialist stands in contrast to the generalist in that the specialist bears only the responsibility for science instruction, while the generalist carries the responsibility for teaching all subjects. However, the science specialist's role from one school to another may vary dramatically. For this study, the researcher selected schools where the science specialist's role and credentials were as follows:

- The science specialist provides science instruction to each class of students for at least one to two instructional segments per week. This occurs in a school where science instruction also takes place in the homeroom, either through direct instruction and/or through integration with the literacy program.

- The science specialist serves as a resource person to provide input regarding pacing and sequencing of the science curriculum.
- The science specialist may be a teacher with extra science experience and interest but who only holds the teaching certificate of regular elementary teachers, or the science specialist may have received extra training in the field of science. The primary distinction between the science specialist and the generalist is that the science specialist has the opportunity to focus only on science instruction.

The researcher selected schools of similar demographics and socioeconomic conditions. Two of the schools use science specialists to provide instruction to students, and two of the schools use generalists to deliver science instruction. Once schools of similar demographics and socioeconomic conditions were identified for the study and the principals informed that their schools would be included in the study (see Appendix C) then the researcher accessed archival data. The data were archived and available upon request from the Georgia Department of Education. The data included two consecutive years' science achievement scores for all of the fifth grade students in each of the participant schools except for the scores of students with IEPs. Additionally, the data included students' racial/ethnic and gender data. The Georgia Department of Education (GaDOE) removed all student-identifying information from the data before it was shared with the researcher. The researcher entered the data into a spreadsheet for analysis.

Data Analysis

The researcher used an analysis of covariance (ANCOVA) to analyze whether there was a significant difference between the mean science achievement scores for the students taught by science specialists and the students taught by generalists while controlling for prior achievement. The ANCOVA is appropriate for comparing the mean scores of one or more dependent variables for two or more groups while controlling one or more extraneous variables between or among the groups (Gall et al., 2007). The dependent variable in this study was science achievement, and the independent variable was the use of elementary science specialists to provide instruction in schools, for which there were two categories: science specialists were used to provide science instruction to students, and science specialists were not used to provide science instruction to students. The prior science achievement of the study participants was the only extraneous variable for which there were controls. The probability of rejecting the null hypothesis when it is true was set at $p < 0.05$. This means that there was a 95% probability that differences between the groups' means was not the result of chance.

The credibility of the results of an ANCOVA requires that certain assumptions not be violated (Warner, 2013). Warner (2013) described the assumptions that must be satisfied for the results of an ANCOVA to be credible, including the assumption that the covariate scores and the dependent variable scores are approximately normally distributed for all independent variable groups. For this study, then, the use of an ANCOVA assumed that the covariate of prior science achievement of students, taken from students' fourth grade science assessment, was approximately normally distributed for both the schools where science specialists are used as well as the schools where science specialists are not used. Furthermore, the researcher assumed that the science achievement scores for both types of schools were close to normally distributed for the students' fifth grade science assessment. Warner also cited the assumption that there is a linear relationship between the covariate and the dependent variable for all independent variable groups. This assumption, as it relates to this study, was that for both types of schools, the students' fourth grade science achievement had a linear relationship with their fifth grade science achievement. Finally, Warner stated that there is an assumption that the variance of the dependent variable scores for each group of independent variable is similar. For this study, this assumption was that the variance of fifth grade science achievement scores for students from schools that use science specialists was similar to the fifth grade science achievement scores for students from schools that do not use science specialists.

The researcher conducted tests to check the assumptions of normality of sampling and homogeneity of variance to ensure that the assumptions of the ANCOVA were not violated. The Kolmogorov-Smirnov test is useful for studies with larger sample sizes such as this one, and it was used to test the assumption of normality (Warner, 2013). Levene's Test for Homogeneity is useful for verifying equal error variance for two groups (Deng, Asma, & Paré, 2014; Gall et al., 2007; Warner 2013) and was used to verify that error variance was equal for both groups. The analysis of variance assumes that there will be equal error variances for both groups. The researcher screened the data for unusual scores or inconsistencies. The researcher identified potential outliers using Box and Whisker plots. According to Howell (2011), outliers may represent legitimate values in a data set, or they may represent errors in data collection. One potential outlier revealed by the Box and Whisker plot is cause for inspection of the data to determine if data collection errors may exist that would need to be corrected (Howell, 2011). The researcher found that the potential outlier represented a legitimate value, and kept the value in the data set. The dependent variable was measured by the scaled score from the GMAS science test, which is measured on a ratio scale, satisfying the assumption of level of measurement. The assumption of independent observations was satisfied by the fact that the scores of students from all of the participant schools are independent of each other.

Mere statistical tests of significance do not provide a measure of the contextual meaning and usefulness of research results (Gall et al., 2007). To determine the practical significance of the difference between the means of the science achievement scores for schools that use science specialists and the science achievement scores of schools that do not use science specialists the researcher used Cohen's *d* test for effect size (Howell, 2011; Warner, 2013). For the purpose of behavioral and social science research, Warner (2013) advised using the effect sizes defined by Cohen (1988), which are 0.20, 0.50, and 0.80 respectively as small, medium, and large.

CHAPTER FOUR: FINDINGS

Overview

The purpose of this quantitative casual-comparative study was to examine the effect of using an elementary science specialist on the science achievement scores of fifth grade students in northeast Georgia schools as measured by the Georgia Milestones Assessment System. The researcher used archival data from 282 students. The researcher also used inferential statistics to compare the means of the scaled science achievement scores of students taught science by science specialists and students taught science by generalists. This study used the ANCOVA model to test the hypothesis and to control for the previous year's science achievement scores.

Research Question

RQ1: Is there a statistically significant difference in science achievement scores between elementary students who receive instruction from a science specialist and those who do not as measured by the Georgia Milestones Assessment while controlling for pretest scores?

Null Hypothesis

$H_0$1: There is no statistically significant difference in science achievement scores between elementary students who receive instruction from a science specialist and those who do not as measured by the Georgia Milestones Assessment while controlling for pretest scores.

Descriptive Statistics

A total of 282 participants were involved in the data analysis, 121 (42.9%) of which received science instruction from specialists and 161 (57.1%) of which received science instruction from a generalist, a specialist being a teacher who only prepares for and delivers science instruction (Baldi, Warner-Griffin, Tadler, 2015; National Research Council, 2014; Olson, Tippett, Milford, Ohana, & Clough, 2015) and a generalist being a teacher who prepares for and delivers instruction for all subjects (Baldi et al., 2015; Gerretson, Bosnick, & Schofield, 2008; Kier & Lee, 2017; National Research Council, 2014; Olson et al., 2015). Table 5 presents the number of students in each group.

Table 5

Number of Students for Each Type of Science Instruction (N = 282)

Type of Science Instruction	*n*	%
Science Specialists Deliver Science Instruction	121	42.9%
Generalists Deliver Science Instruction	161	57.1%

Science scores for 2015-2016 (pretest) served as the covariate, preexisting science achievement. For the overall sample (n = 282), pretest scores ranged from 413 to 626, with M = 525.54 and SD = 40.61. For the students who received science instruction from science specialists (n = 121), pretest scores ranged from 413 to 590, with M = 521.99 and SD = 39.04. For the students who received science instruction from generalists (n = 161), posttest scores ranged from 447 to 626, with M = 533.22 and SD = 39.70. Table 6 presents the descriptive statistics for all students.

The researcher used science scores for 2016-2017 (posttest) to measure the dependent variable. For the overall sample (n = 282), posttest scores ranged from 407 to 680, with M = 541.03 and SD = 55.51. For the students who received science instruction from science specialists (n = 121), posttest scores ranged from 407 to 655, with M = 530.12 and SD = 51.70. For the students who received science instruction from generalists (n = 161), posttest scores ranged from 423 to 680, with M = 549.24 and SD = 57.00. Table 6 below presents the descriptive statistics for all students.

Table 6

Descriptive Statistics for Milestones Science Scaled Scores (N=282)

Milestones Science Scaled Score	*n*	*Min*	*Max*	*M*	*SD*
2015-2016 (Pretest)					
Overall sample	282	413	626	524.54	40.61
Science specialist	121	413	590	512.99	39.04
Generalist	161	447	626	533.22	39.70
2016-2017 (Posttest)					
Overall sample	282	407	680	541.03	55.51
Science specialist	121	407	655	530.12	51.70
Generalist	161	423	680	549.24	57.00

Results

Hypothesis

The null hypothesis for this study is:

$H_0$1: There is no statistically significant difference in science achievement scores between elementary students who receive instruction from a science specialist and those who do not as measured by the Georgia Milestones Assessment while controlling for pretest scores.

The researcher used An ANCOVA to test this hypothesis. An ANCOVA is an appropriate tool when assessing differences in a continuous dependent variable between groups, while controlling for another variable (Tabachnick & Fidell, 2013). The dependent variable was measured by the posttest scores. The independent variable was type of science instruction, whether students received science instruction from science specialists or from generalists. The covariate for the analysis was pretest scores.

Potential outliers were examined through use of boxplots (see Figures 1 and 2) and standardized values. The boxplot for pretest scores indicated one potential outlier (413). Tabachnick and Fidell (2013) suggested that outliers are present for *z*-scores falling outside the range, ± 3.29 standard deviations away from the mean. There were no such cases for pretest and posttest scores; therefore, the researcher removed no participants for the inferential analysis.

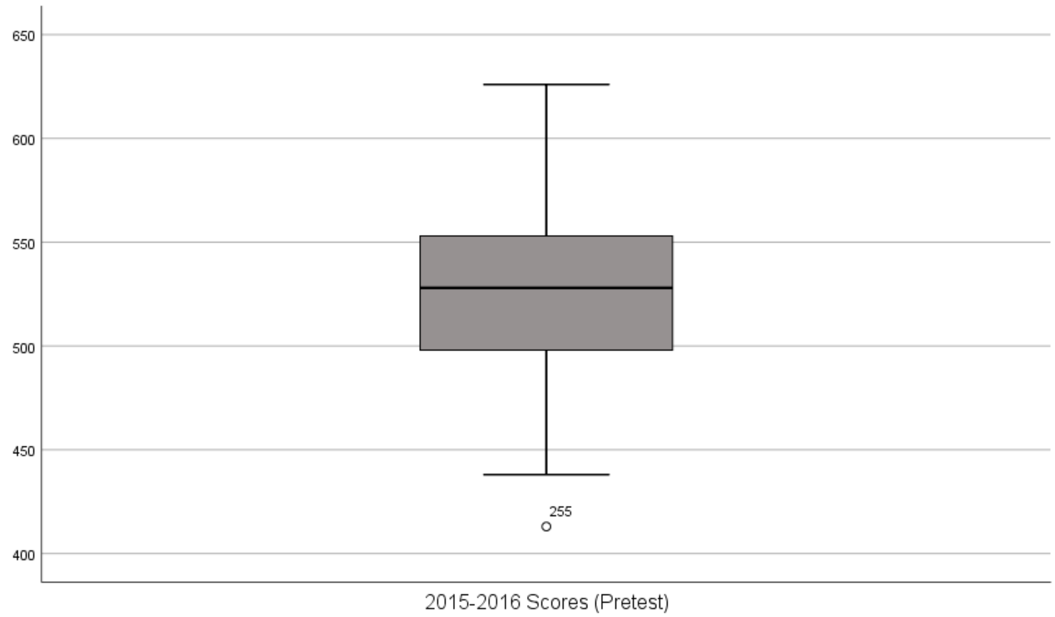

Figure 1. Boxplot for pretest scores.

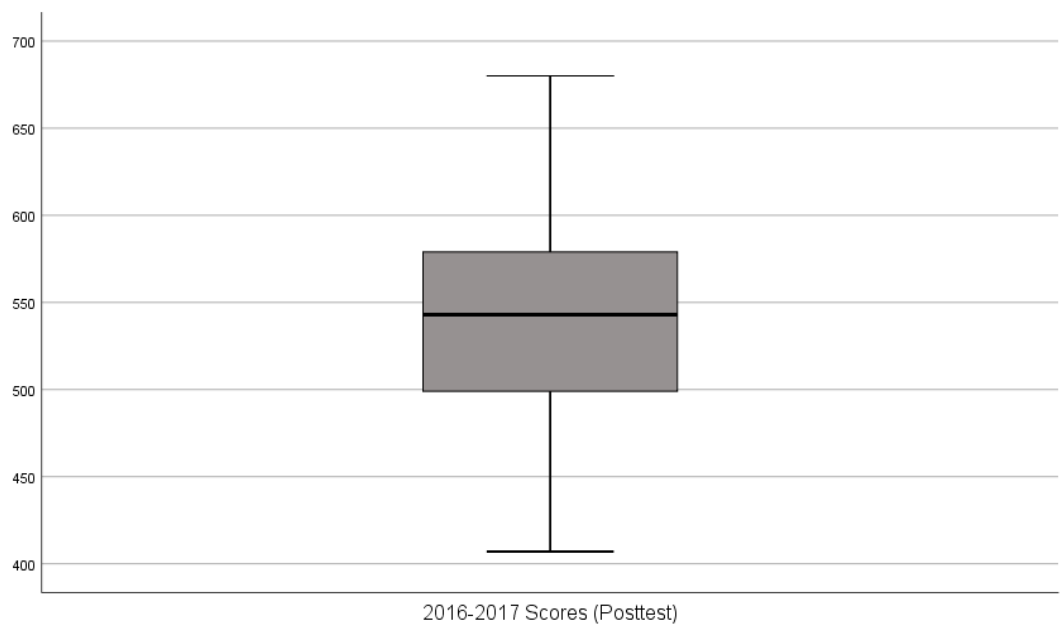

Figure 2. Boxplot for posttest scores.

Three assumption tests were administered to help ensure the validity of the ANCOVA (Warner, 2013). The Kolmogorov-Smirnov Test was used to test the assumption of normality of the covariate scores and the dependent variable scores, which were the 2015-2016 fourth grade Milestones scaled scores and the 2016-2017 fifth grade Milestones scaled scores respectively (Warner, 2013). The findings of the Kolmogorov-Smirnov tests were non-significant (*p* = .200) indicating the distribution of each variable was approximately normal (Warner, 2013). Table 7 presents the findings of the Kolmogorov-Smirnov tests for both groups of test scores. Figure 3 shows frequency histograms representing the pretest and posttest science achievement scores.

Table 7

Kolmogorov-Smirnov Test of Normality

Specialist	2015-2016 Scores		2016-2017 Scores	
	Kolmogorov-Smirnov Test Statistic	*p*	Kolmogorov-Smirnov Test Statistic	*p*
Science specialist	0.06	.200	0.06	.200
Generalist	0.05	.200	0.05	.200

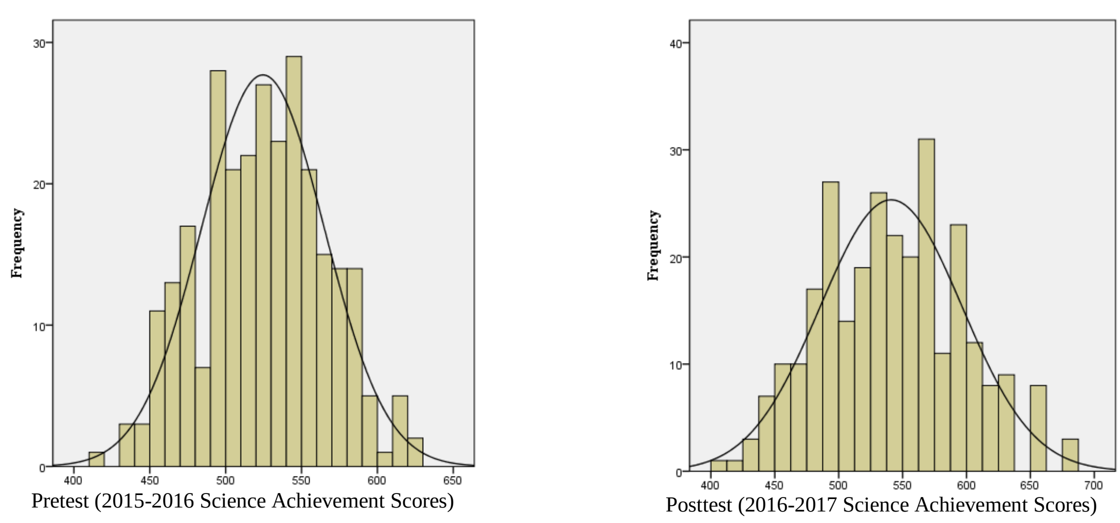

Figure 3. Pretest and posttest frequency histograms for science achievement scores.

The researcher used a scatterplot to test the assumption of linearity between the covariate scores and the dependent variable scores, which were the 2015-2016 fourth grade Milestones scaled scores and the 2016-2017 fifth grade Milestones scaled scores, respectively (see Figure 4). The scatterplot depicted an approximately linear association; therefore, the assumption was met (Gall, Gall, & Borg, 2007).

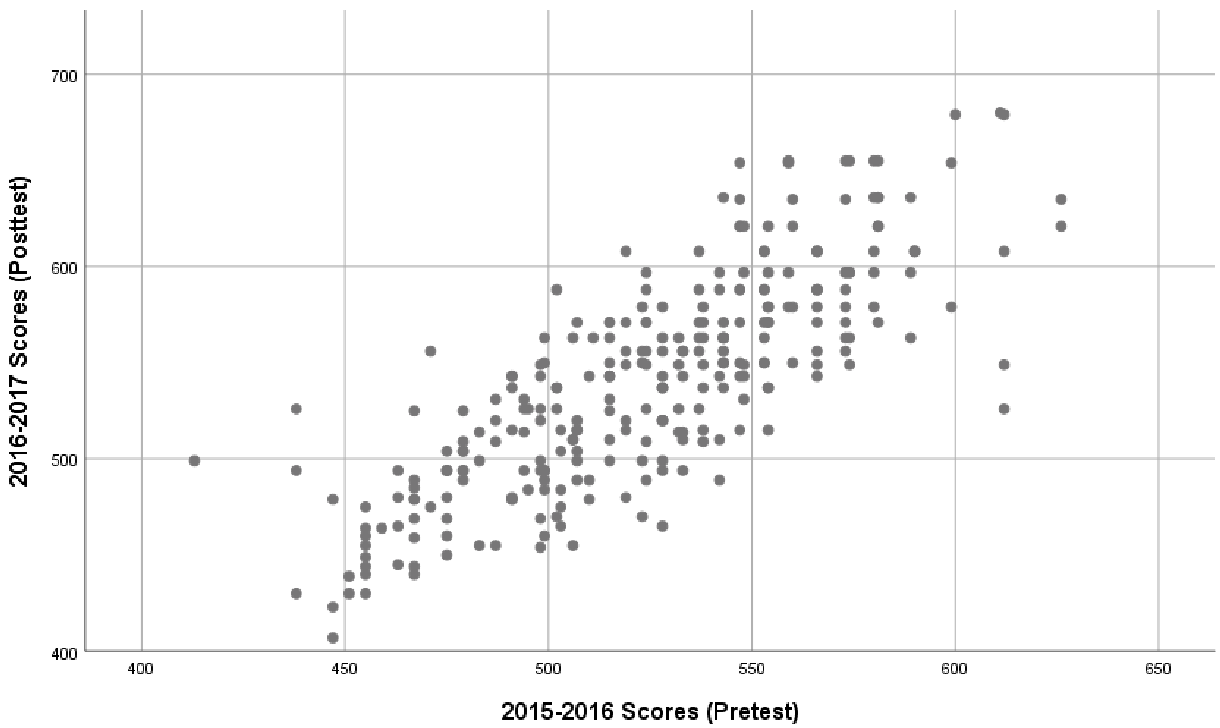

Figure 4. Scatterplot between Pretest and Posttest Scores.

The researcher used Levene's Test for Homogeneity of Variance (as cited in Olkin & Hotelling, 1960) to assess for similar variance of the dependent variables between each group. The result of Levene's test was not significant, F(1, 280 = 1.30, p = .256) indicating that the assumption of homogeneity of variance was met (Deng, Asma, & Paré, 2014; Gall et al., 2007; Warner 2013).

Results. The results of the ANCOVA were not significant, F(1, 279) = 0.56, p = .455, indicating there were no statistically significant differences in posttest scores between elementary students who received instruction from science specialists and those who did not, while controlling for pretest scores. Therefore, the null hypothesis for the research question was accepted. The findings of the ANCOVA are presented in Table 8. The marginal means and standard deviations are presented in Table 9.

Table 8

ANCOVA Results for Posttest Scores

Term	*SS*	*df*	*F*	*p*	η_p^2
Type of Teacher	630.06	1	0.56	.455	0.00
Pretest Scores	525965.89	1	466.45	< .001	0.63
Residuals	314601.52	279			

Table 9

Marginal Means for Posttest Scores by Type of Teacher Delivering Science Instruction

Specialist	Marginal Posttest Means	*SE*	*n*
Science specialist	539.69	2.68	161
Generalist	542.81	3.11	121

CHAPTER FIVE: CONCLUSIONS

Overview

In this chapter the results of this study are discussed in relation to what was presented in the literature review. Furthermore, a discussion regarding this study's results and its stated research question follows. The implications of this study are considered along with its limitations. Finally, recommendations for further research are suggested.

Discussion

The purpose of this causal-comparative study was to determine if there is a statistically significant difference between the science achievement scores of fifth grade students who attend schools where science instruction is delivered by science specialists and those who attend schools where science instruction is delivered by regular classroom teachers, who are considered generalists. The study examined the following research question: Is there a statistically significant difference in science achievement scores between elementary students who receive instruction from a science specialist and those who do not as measured by the Georgia Milestones Assessment while controlling for pretest scores?

The research question distinguished between two possible types of teachers who deliver science instruction to elementary students: science specialists and generalists. Science specialists represent those teachers who are charged only with teaching science and who may have more extensive training in science content and pedagogy. Generalists represent those teachers who are charged with teaching all subjects in an elementary classroom, and therefore, who do not have a singular focus for their instructional preparation. The researcher investigated the impact of these different types of teachers on the science achievement of fifth grade students. The null hypothesis stated that there would be no statistically significant difference in science achievement scores between elementary students who receive instruction from science specialists and those who receive instruction from generalists as measured by the Georgia Milestones Assessment while controlling for pretest scores? The results of the ANCOVA displayed in Table 8 for posttest science achievement scores, while controlling for pretest science achievement scores, indicated that there was no statistically significant difference $F(1, 279) = 0.56$, $p = .455$. According to Gall, Gall, and Borg (2007) and Warner (2013), a significant difference may be concluded if $p < .05$, leading to a rejection of the null hypothesis. Since the results of the ANCOVA for this study yielded a p value greater than .05, the null hypothesis was not rejected.

While the opportunity for students to have engaging learning experience in science class has been linked to higher levels of science achievement (Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Jones, Childers, Stevens, & Whitley, 2012; Qarareh, 2016), the results of this study showed that there was no statistically significant difference between the science achievement scores of students receiving science instruction from specialists and those receiving science instruction from generalists. As Table 6 shows, the growth in students' mean science achievement from pretest scores to posttest scores for those who were taught by specialists and generalists were 17.13 and 16.02 respectively. The difference between the mean growth scores of these two groups of students was only 1.11 points in favor of the students taught by specialists. The results of this study, which focused on the difference in science achievement for elementary students taught by science specialists and those taught by generalists, do not align with the results of studies that found a favorable difference in science achievement for elementary students taught by teachers who use more hands-on, authentic learning experiences (Diaconu et al., 2012; Jones et al., 2012; Qarareh, 2016). While this study examined the difference in science achievement for the students of elementary science specialists and generalists, it did not control for the teaching strategies used by either the science specialists or the generalists. As such, from this study it cannot be said with certainty how the instructional strategies may have varied between the science specialists and generalists or the impact that varying instructional strategies may have had on students' science achievement. Instead, this study only considered the distinction between science achievement for elementary students whose teachers specialize in teaching science and students whose teachers are generalists.

The point of science instruction is to facilitate the learning of science for students. In the Theoretical Framework section of this paper, an explanation was presented of how Jean Piaget's (1972) theory of cognitive development described how children respond to new information either by the process of assimilation or the process of accommodation (Bakken et al., 2001; Inhelder & Piaget, 1969,1950; Lawson, 2008; Piaget, 1962). These processes would also be the means by which students take in new information during science instruction (Crawford, 2007). Studies have shown that hands-on learning is the best way to advance these cognitive processes (Barak & Dori, 2011; Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Jones, Childers, Stevens, & Whitley, 2012) and to stimulate multiple senses during the learning process (Katai, Toth, & Adorjani, 2014). However, this study, which focused on the effects of using science specialists to teach elementary science, did not find a statistically significant difference between the science achievement scores of students taught by science specialists and those taught by generalists.

Prior research indicated that the use of hands-on learning that incorporates the practices of science is more effective than instruction that focuses solely on the content of science (Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Harman, Cokelez, Dal, & Alper, 2016). These practices include measuring, observing, collecting data, investigating, asking questions, and solving problems (Amirshokoohi, 2016; Dejarnette, 2016; Kier & Lee, 2017; Maxwell, Lambeth, & Cox, 2015; National Research Council, 2012; National Research Council 2013). It has been further demonstrated that science specialists are better prepared to provide these kinds of learning experiences for elementary students (Campbell & Chittleborrough, 2014). However, the results of this study did not indicate any statistically significant advantage in the area of science achievement for elementary students taught by science specialists compared to elementary students taught by generalists.

The study conducted by Maxwell, Lambeth, and Cox (2015) examined the effect of using inquiry-based learning (IBL) practices on science achievement, interest in science, and engagement in science for fifth grade students. Maxwell, Lambeth, and Cox's study involved 42 students from two different classes, one where IBL practices were used. Traditional instructional practices were used in the other class which served as the control group. Maxwell, Lambeth, and Cox found no statistically significant differences between the groups in the areas of student achievement and student interest, but higher engagement levels for the students in the IBL classroom. Maxwell, Lambeth, and Cox used pretests and posttests over a six-week study to measure science achievement while this study relied on the Georgia Milestones Assessment System (GMAS) to measure science achievement. While two different assessments were used, both the study conducted by Maxwell, Lambeth, and Cox and this study found no significant improvement in science achievement for the fifth grade students in the studies. Maxwell, Lambeth, and Cox considered the effects of IBL while this study examined the effects of using science specialists, which some have said may be more likely to employ IBL practices (Campbell & Chittleborrough, 2014; Levy, Jia, Marco-Bujosa, Gess-Newsome, & Pasquale, 2016). Both the Maxwell, Lambeth, and Cox study and this study looked at how science achievement was impacted, but this study, unlike the Maxwell, Lambeth, and Cox study, did not consider levels of student engagement in science or students' interest in science.

Campbell and Chittleborrough (2014) reported on a study grounded on the premise that the use of elementary science specialists to work with both the development of other teachers' science knowledge and instructional skills as well as with students would produce benefits in a variety of ways, including better science instruction, heightened student engagement with science, greater likelihood that students would aspire for further study in science, and higher science achievement. The study reported by Campbell and Chittleborrough differed in several critical ways from this study. The Campbell and Chittleborrough study examined the effects of elementary science specialists who played a significant role in developing the science knowledge and instructional skills of generalist teachers in their buildings. This study examined the effects of elementary science specialists in schools where the science specialists focused more on their own science instruction and less on the development of generalists in their respective buildings. Furthermore, the science specialists in the Campbell and Chittleborrough study were provided ongoing professional development over the course of the study. There was no known ongoing professional development specifically designed for the science specialists in this study. Finally, the study reported by Campbell and Chittleborrough examined the results in the schools of 42 different elementary science specialists. This study examined the results of using elementary science specialists in only two different schools compared to two elementary schools where science specialists are not used. While the study reported by Campbell and Chittleborrough did not include a measure of the effect of elementary science specialists on students' science achievement, the authors acknowledged the intention to extend their study to include such measures. That notwithstanding, Campbell and Chittleborrough did report that the results of using elementary science specialists included an increase in elementary students' engagement with science and a higher level of confidence in the area of science instruction expressed by both science specialists as well as the generalists with whom they worked. This study did not consider the confidence levels of teachers, generalists or specialists, or the engagement level of students with science. This study did examine the effects of elementary science specialists on science achievement as measured by the Georgia Milestones Assessment System (GMAS) and found no significant difference between students taught by specialists and those taught by generalists.

The study conducted by Diaconu, Radigan, Suskavcevic and Nichol (2012) reported on the effects of providing weekly science content and pedagogy training for approximately 80 elementary teachers. These teachers worked in urban school districts that served mainly high-poverty and high-minority students. The teachers in the Diaconu et al. study were expected to employ inquiry-based learning techniques in their classrooms similar to the pedagogical training they received. The Diaconu et al. study did not examine the effects of the weekly science content and pedagogical professional development for elementary teachers on students' science achievement. Diaconu et al. found that the teachers in their study demonstrated an increase in their content knowledge, in their use of inquiry-based instructional strategies, and in their leadership skills. The Diaconu et al. study differed from this study as this study examined the effect of elementary science specialists on the science achievement of elementary students from rural, mostly white schools from north Georgia. There were 80 elementary teachers in the Diaconu et al. study while this study only examined science teachers in four elementary schools. Furthermore, this study did not include an examination of specific science content or pedagogy training for elementary teachers or the effects of inquiry-based science instruction. Diaconu et al. presented no findings related to students' science achievement, while this study's sole focus was on effects to students' science achievement, of which no significant effects were found.

Qarareh (2016) conducted a study that investigated the effect of using the constructivist learning model (CLM) on eighth grade students' science achievement and scientific thinking. In his study Qarareh investigated 136 students from four different eighth grade science classes. Qararehnarrowed his study to the instruction and achievement in the field of light and optics. Qarareh found that the students in the CLM classes achieved at higher levels than their counterparts in the control classrooms, and, he found that the students in the CLM classes developed higher proficiency in the area of scientific thinking. Qarareh did not find any statistically significant difference in the effect of the CLM between genders. While Qarareh found improved science achievement for the students in his study, this study did not find a statistically significant difference in students' science achievement. However, Qarareh considered the effects of the CLM while this study investigated the effects of using elementary science specialists. Quarareh looked at the effects on science achievement for eighth grade students, while this study considered the effects on science achievement for fifth grade students. Unlike Quarareh's study, this study did not consider how students of different genders may have been affected differently by the independent variable. Qarareh measured science achievement with a test that focused on the learning objectives prescribed by an eighth grade textbook while this study relied on the Georgia Milestones Assessment System (GMAS). The GMAS assesses students' learning related to all of the learning objectives for the whole of Georgia's fifth grade science curriculum (Georgia Department of Education, 2017a).

Several other studies have also concluded that students who receive science instruction in a traditional manner, focusing more on science content than on science practices, are less likely to gain a deep understanding of the content (Aydeniz, Cihak, Graham, & Retinger, 2012;

Maxwell, Lambeth, & Cox, 2015; National Research Council, 2012; National Research Council, 2013). But, for the students who were the subjects in this study, there was no statistically significant difference between the science achievement scores of students who were taught by specialists and those who were taught by generalists.

The results of this study align with the findings of a similar study conducted by Levy, Jia, Marco-Bujosa, Gess-Newsome, and Pasquale (2016), who concluded that multiple factors impacted elementary students' science achievement. Levy et al. found that having a science specialist delivering instruction to elementary students did not always yield higher science achievement results. The other factors identified by Levy et al. that impacted science achievement for elementary students included the overall value placed on science in the school; the principal's support for the science program in the school; the resources made available for the science program; the quality of teachers in the school; the quality of instruction in the school; and the quantity of time allocated for science instruction in the school. Levy et al. further cited many additional underlying features that impacted each of these main factors. This study examined the effect of science specialists compared to generalists on elementary science achievement without regard to the many underlying factors cited by Levy et al.

Implications

This study has contributed to the body of knowledge related to the effectiveness of using science specialists to deliver science instruction to elementary students compared to the use of generalists to deliver science instruction to elementary students. Prior studies have been conducted but have yielded mixed results regarding the advantages of science specialists compared to generalists for improving science achievement among elementary students (Levy, Jia, Marco-Bujosa, Gess-Newsome, & Pasquale, 2016). While this study showed a slightly higher growth in science achievement from pretest scores to posttest scores for students being taught by science specialists (refer to Table 6), the results of the ANCOVA (refer to Table 8) indicated that the difference between the pretest to posttest growth for the two groups of students was not statistically significant. From this, it stands that there are no advantages afforded by the use of science specialists for improving science achievement among the sample population studied.

In light of the studies that have linked engaging students with the use of hands-on learning, critical thinking, observing, questioning, investigating, and problem solving to higher science achievement (Diaconu, Radigan, Suskavcevic, & Nichol, 2012; Harman, Cokelez, Dal, & Alper, 2016) and in light of the assertion that science specialists are more likely to employ such instructional strategies (Campbell & Chittleborrough, 2014; Levy, Jia, Marco-Bujosa, Gess-Newsome, & Pasquale, 2016) it may seem that a direct connection could be drawn between the use of elementary science specialists and higher science achievement. However, the results of this study do not support such a direct connection as the student subjects in this study who received science instruction from science specialists did not achieve at a significantly higher level in science than their counterparts who received science instruction from generalists. The lack of a direct connection between the use of elementary science specialists and higher science achievement is consistent with the findings of Marco-Bujosa and Levy (2016) who found that there are other factors that may negate the advantages otherwise afforded by the use of science specialists.

Studies have shown that American students lag behind their counterparts in many other countries around the world in the area of science (OECD, 2016b). A study conducted by Schmitt (2013) documented that Georgia students' proficiency in science was below the national average.

Since this study did not show a statistically significant difference in the science achievement of students taught by science specialists, it seems unlikely that the closure of gaps in the area of science achievement would be accomplished solely by the use of elementary science specialists. This is consistent with the findings of Levy, Jia, Marco-Bujosa, Gess-Newsome, and Pasquale (2016), who found that there are multiple factors that impact elementary students' science achievement, including the overall value placed on science in the school; the principal's support for the science program in the school; the resources made available for the science program; the quality of teachers in the school; the quality of instruction in the school; and the quantity of time allocated for science instruction in the school. Thus, it seems that the investment in having elementary science specialists would not be prudent unless other important factors affecting science achievement were also addressed.

Limitations

This study was limited to schools in Georgia. In Georgia there is no clear definition of what an elementary science specialist is. In this study a science specialist was defined as an educator who has had special training in science content and pedagogy and is able to concentrate instruction in only the area of science (Baldi, Warner-Griffin, Tadler, 2015; National Research Council, 2014; Olson, Tippett, Milford, Ohana, & Clough, 2015). However, the amount of special training that distinguishes a science specialist may vary from school to school and certainly from state to state. While the teachers in the schools selected for this study matched this study's stated criteria for science specialists, the researcher was not able to observe the actual science instruction in any of the schools to ensure consistency of instructional practices and quality. The possibility of variability between instructional quality and practices for the teachers in this study represents an internal threat. To mitigate this threat, the researcher relied on a survey in the form of a questionnaire (see Appendix B) to help verify the type of science teachers used in the schools selected for this study.

The possibility of the students in this study having different levels of prior science achievement presents an internal threat. Students with a higher level of prior science achievement may have a greater aptitude for additional learning in science, which may impact the measure of science achievement for students. To help control for prior science achievement this study used an ANCOVA for which prior science achievement was the covariate. The prior science achievement was represented by the students' fourth grade science achievement scores, which was the year prior to this study's posttest.

As has already been cited in this study, there are several other factors that have been shown to impact elementary science achievement besides the type of teacher delivering science instruction, including the overall value placed on science in the school; the principal's support for the science program in the school; the resources made available for the science program; the quality of teachers in the school; the quality of instruction in the school; and the quantity of time allocated for science instruction in the school (Levy, Jia, Marco-Bujosa, Gess-Newsome, & Pasquale, 2016). The presence of these additional variables presents an internal threat in this study. This study was limited in that these other factors were not able to be controlled.

The instrument used for measuring science achievement in this study was the state of Georgia's standardized, end-of-grade science achievement test, which is included with the Georgia Milestones Assessment System (GMAS). The researcher was in no way a part of the development or review of the GMAS questions used for measuring science achievement. The possibility of an internal threat exists in that the GMAS questions for fourth grade science achievement and those for fifth grade science achievement, which represented the pretest and posttest for this study, may not perfectly measure science achievement in a consistent fashion. Thus, other measurements of science achievement may yield different results. However, the Georgia Department of Education (GaDOE), which is responsible for the development of the GMAS, claims that appropriate steps were taken in the development of the GMAS to ensure that validity and reliability standards were met in accordance with the Standards for Educational and Psychological Testing established by the American Educational Research Association, the American Psychological Association, and the National Council on Measurement in Education (Georgia Department of Education, 2017b).

This study focused on a population of fifth grade students from rural areas in northeast Georgia. As was shown in Table 2, the schools in this study served mostly white students, with only a few students from minority groups. Furthermore, as shown in Table 4, most of the students in the schools for this study come from economically disadvantaged backgrounds. This study's results are limited to the specific population of students served in the schools included in this study.

Recommendations for Future Research

After careful consideration and reflection related to this study, the researcher acknowledges that there are opportunities for future study that would further advance the body of knowledge related to the use of elementary science specialists including the following:

1. Refine the results of this study by using pretest scores from students who all had the same type of science teacher prior to the pretest and half of which had a change in type of science teacher prior to the posttest.
2. Conduct a study that further isolates the effects of using elementary science specialists by controlling for other variables that have been shown to impact science

achievement, including the overall value placed on science in the school; the principal's support for the science program in the school; the resources made available for the science program; the quality of teachers in the school; the quality of instruction in the school; and the quantity of time allocated for science instruction in the school.

3. Facilitate a study for which the focus is shifted from the type of teacher (science specialist or generalist) as the independent variable to the style of instruction (inquiry based learning or traditional) as the independent variable.
4. Expand the size of the study to include more students from more schools from a broader area.
5. Examine the effects of using science specialists with specific subgroups, including gender, minority status, and socioeconomic status.
6. Conduct a longitudinal study that considers science achievement over an extended period of time rather than just a single year.
7. Consider a mixed-methods study that considers both the quantitative results derived from science achievement scores and the qualitative findings derived from surveys and interviews that solicit the feelings of students and teachers about science instruction and learning.
8. Measure the difference in science achievement for students taught by elementary science specialists and those taught by generalists using an instrument for assessing science achievement other than the GMAS.

Each of these suggested areas for further study may provide additional and valuable insight related to effective science instruction and the improvement of science achievement for elementary students.

REFERENCES

Abegglen, S., & Bustillos, J. (2016). Science education: Beyond a liminal understanding of knowledge production and dissemination. *Journal of Education in Science, Environment and Health, 2*(1), 13-20. Retrieved 12-26-16 from: http://files.eric.ed.gov/fulltext/ED563999.pdf

Abell, S. K. (1990). A case for the elementary science specialist. *School Science & Mathematics, 90*(4), 291-301. doi:10.1111/j.1949-8594.1990.tb15547.x

Adamson, K., Santau, A., & Lee, O. (2013). The impact of professional development on elementary teachers' strategies for teaching science with diverse student groups in urban elementary schools. *Journal of Science Teacher Education, 24*(3), 553-571. doi:10.1007/s10972-012-9306-z

Ajilore, O. (2013). Estimating the spillover effects of school district demographics on per-pupil spending. *Journal of Education Finance, 39*(2), 101-114. doi:10.1353/jef.2013.0014

Alvermann, D. E., & Jackson, G. (2016). Alvermann & Jackson: Response to "Beyond the common core: Examining 20 years of literacy priorities and their impact on struggling readers". *Literacy Research and Instruction, 55*(2), 107-110. doi:10.1080/19388071.2016.1135381

American Association for the Advancement of Science (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Amirshokoohi, A. (2016). Impact of STS issue-oriented instruction on pre-service elementary teachers' views and perceptions of science, technology, and society. *International Journal of Environmental and Science Education, 11*(4), 359-387.

Anez, G., Chancey, C., Grinev, A., & Rios, M. (2012). Dengue virus and other arboviruses: A global view of risks. *ISBT Science Series*, *7*(1), 274-282. doi:10.1111/j.1751-2824.2012.01602.x

Anghel, D. (2015). The role of instruction in supporting student explanations during science learning. *Scientific Journal of Humanistic Studies*, *7*(12), 63-67. Retrieved 12-26-16 from: http://web.a.ebscohost.com.ezproxy.liberty.edu/ehost/pdfviewer/pdfviewer?sid=b2a3374b-b887-42aa-a773-18d77cb4ad4c%40sessionmgr4007&vid=8&hid=4106

Aydeniz, M., Cihak, D. F., Graham, S. C., & Retinger, L. (2012). Using inquiry-based instruction for teaching science to students with learning disabilities. *International Journal of Special Education, 27*(2), 189-206.

Ashton, P. (1984). Teacher efficacy: A motivational paradigm for effective teacher education. *Journal of Teacher Education, 35*(5), 28-32. doi: 10.1177/002248718403500507

Bakken, L., Thompson, J., Clark, F. L., Johnson, N., & Dwyer, K. (2001). Making conservationists and classifiers of preoperational fifth-grade children. *Journal of Educational Research*, *95*(1), 56. Retrieved 1-3-17 from: http://web.a.ebscohost.com.ezproxy.liberty.edu/ehost/pdfviewer/pdfviewer?sid=b2a3374b-b887-42aa-a773-18d77cb4ad4c%40sessionmgr4007&vid=11&hid=4106

Baldi, S., Warner-Griffin, C., Tadler, C. (2015). Education and certification qualifications of public middle grades teachers of selected subjects: Evidence from the 2011-12 Schools and Staffing Survey. *NCES 2015*-815.

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., Weis, A. M., & Horizon Research, I. (2013). Report of the 2012 National Survey of Science and Mathematics Education.

Barak, M., & Dori, Y. (2011). Science education in primary schools: is an animation worth a thousand pictures?. *Journal of Science Education & Technology, 20*(5), 608-620. doi:10.1007/s10956-011-9315-2

Bazzul, J. (2015). The sociopolitical importance of genetic, phenomenological approaches to science teaching and learning. *Cultural Studies of Science Education, 10*(2), 495-503. doi:10.1007/s11422-014-9605-0

Blank, R. K. (2013). Science instructional time is declining in elementary schools: What are the implications for student achievement and closing the gap?. *Science Education, 97*(6), 830-847. doi:10.1002/sce.21078

Brobst, J., Markworth, K., Tasker, T., & Ohana, C. (2017). Comparing the preparedness, content knowledge, and instructional quality of elementary science specialists and self-contained teachers. *Journal of Research in Science Teaching, 54*(10), 1302-1321. doi:10.1002/tea.21406

Bybee, R. W. (2013). The next generation science standards and the life sciences. *Science & Children, 50*(6), 7-14.

Campbell, C., & Chittleborough, G. (2014). The "new" science specialists: Promoting and improving the teaching of science in primary schools. *Teaching Science, 60*(1), 19-29. Retrieved 12-23-16 from: http://web.a.ebscohost.com.ezproxy.liberty.edu/ehost/pdfviewer/pdfviewer?sid=b2a3374b-b887-42aa-a773-18d77cb4ad4c%40sessionmgr4007&vid=20&hid=4106

Carrier, S. J., Thomson, M. M., Tugurian, L. P., & Stevenson, K. T. (2014). Elementary science education in classrooms and outdoors: Stakeholder views, gender, ethnicity, and testing. *International Journal of Science Education*, *36*(13), 2195-2220. doi:10.1080/09500693.2014.917342

Century, J., Rudnick, M., & Freeman, C. (2008). Accumulating knowledge on elementary science specialists: A strategy for building conceptual clarity and sharing findings. *Science Educator, 17*(2), 31-44.

Chisolm, C. L. (2016). *The impact of access to school-based parent resource centers on parents' perceptions of school climate and students' academic achievement* (Unpublished doctoral dissertation). Indiana University of Pennsylvania, Indiana, PA. Retrieved 4-13-17 from: http://knowledge.library.iup.edu/cgi/viewcontent.cgi?article=2287&context=etd

Chronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16(3), 297-334. doi:10.1007/bf02310555

Cohen, J. (1988). *Statistical power analysis for the behavior sciences* (2nd ed.). St. Paul, MN: West Publishing Company.

Coleman, T. W. (2014). The CIA helped win the space race. *International Policy Digest*, *1*(7), 87-90. Retrieved 12-23-16 from: http://web.a.ebscohost.com.ezproxy.liberty.edu/ehost/pdfviewer/pdfviewer?sid=b2a3374b-b887-42aa-a773-18d77cb4ad4c%40sessionmgr4007&vid=25&hid=4106

Colley, C., & Windschitl, M. (2016). Rigor in elementary science students' discourse: The role of responsiveness and supportive conditions for talk. *Science Education, 100*(6), 1009-1038.

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching*, *44*(4), 613-642. doi:10.1002/tea.20157

Dalvi, T., & Wendell, K. (2015). Community-based engineering. *Science and Children, 53*(1), 67-73.

Dejarnette, N. K. (2016). America's children: Providing early exposure to STEM (science, technology, engineering and math) initiatives. *Reading Improvement, 53*(4), 181-187.

Deng, W. Q., Asma, S., & Paré, G. (2014). Meta-analysis of SNPs involved in variance heterogeneity using Levene's Test for Equal Variances. *European Journal of Human Genetics, 22*(3), 427-430. doi:10.1038/ejhg.2013.166

Diaconu, D. V., Radigan, J., Suskavcevic, M., & Nichol, C. (2012). A multi-year study of the impact of the Rice model teacher professional development on elementary science teachers. *International Journal of Science Education*, *34*(6), 855-877. doi:10.1080/09500693.2011.642019

Duschl, R. A. (2012). The second dimension -- Crosscutting concepts. *Science & Children, 49*(6), 10-14.

Eisenhower, D. D. (1958). Recommendations relative to our educational system. *Science Education*, *42*(2), 103-106. doi:10.1002/sce.3730420203

Ewing, J. C., Foster, D. D., & Whittington, M. S. (2011). Explaining student cognition during class sessions in the context Piaget's theory of cognitive development. *NACTA Journal*, *55*(1), 68-75.

Gall, M., Gall, J., & Borg, W. (2007). *Educational research: An introduction* (8th ed.). Boston, MA: Pearson.

Georgia Department of Education (2016a). Science Georgia standards of excellence. Retrieved 12-31-17 from: https://www.georgiastandards.org/Georgia-Standards/Documents/Science-Fifth-Grade-Georgia-Standards.pdf

Georgia Department of Education (2016b). Validity and reliability for the 2015-2016 Georgia Milestones Assessment System. Retrieved 4-30-17 from: http://www.gadoe.org/Curriculum-Instruction-and-Assessment/Assessment/Documents/Milestones/2015-16_Georgia_Milestones_Validity_and_Reliability_Brief.pdf

Georgia Department of Education (2017a). Frequently asked questions Georgia Milestones Assessment System end of course measures scores and reports. Retrieved 4-30-17 from: https://www.gadoe.org/Curriculum-Instruction-and-Assessment/Assessment/Documents/Milestones/Milestones%20FAQS_EOC%20FINAL.pdf

Georgia Department of Education (2017b). Georgia Milestones Assessment System assessment guide: Grade 5. Retrieved 12-31-17 from: https://lorpub.gadoe.org/xmlui/bitstream/handle/123456789/49665/Gr_05_Assessment_Guide_10.25.17.pdf?sequence=1

Georgia Department of Education (2017c). Validity and reliability for the 2016-2017 Georgia Milestones Assessment System. Retrieved 10-7-17 from: http://www.gadoe.org/Curriculum-Instruction-and-Assessment/Assessment/Documents/Milestones/2016-17_Georgia_Milestones_Validity_and_Reliability_Brief.pdf

Gerretson, H., Bosnick, J., & Schofield, K. (2008). A case for content specialists as the elementary classroom teacher. *Teacher Educator*, *43*(4), 302-314. doi.org/10.1080/08878730802249866

Ghazi, S. R., & Ullah, K. (2016). Concrete operational stage of Piaget's cognitive development theory: An implication in learning mathematics. *Gomal University Journal of Research*, *32*(1), 9-20.

Gibbons, B. A. (2003). Supporting elementary science education for English learners: A constructivist evaluation instrument. *Journal of Educational Research, 96*(6), 371-380.

Gillies, R., & Nichols, K. (2015). How to support primary teachers' implementation of inquiry: Teachers' reflections on teaching cooperative inquiry-based science. *Research in Science Education*, *45*(2), 171-191. doi:10.1007/s11165-014-9418-x

Glaser, B., & Vitello, J. (2016). US-China relations: Xi's first state visit to US: Pomp and progress. *Comparative Connections: A Triannual E-Journal on East Asian Bilateral Relations*, *17*(3), 21-38.

Guthrie, J. W., & Ettema, E. A. (2012). Public schools and money. *Education Next, 12*(4), 18-23.

Hanuscin, D. L. (2007). The use of specialized laboratory facilities for science in elementary schools: A call for research. *Journal of Elementary Science Education, 19*(2), 59-64.

Harman, G., Cokelez, A., Dal, B., & Alper, U. (2016). Pre-service science teachers' views on laboratory applications in science education: The effect of a two-semester course. *Universal Journal of Educational Research, 4*(1), 12-25.

Harris, C. J., Penuel, W. R., D'Angelo, C. M., DeBarger, A. H., Gallagher, L. P., Kennedy, C. A., & Krajcik, J. S. (2015). Impact of project-based curriculum materials on student learning in science: Results of a randomized controlled trial. *Journal of Research in Science Teaching, 52*(10), 1362-1385. doi:10.1002/tea.21263

Hinde, E. R., & Perry, N. (2007). Elementary teachers' application of Jean Piaget's theories of cognitive development during social studies curriculum debates in Arizona. *Elementary School Journal, 108*(1), 63-79.

Hise, N. A. (2016). *The relationship between test scores on multiple choice high-stakes tests and high-stakes tests that include constructed responses* (Doctoral dissertation). Retrieved from Doctoral Dissertations and Projects. (1294) http://digitalcommons.liberty.edu/doctoral/1294

Hofstein, A., Eilks, I., & Bybee, R. (2011). Societal issues and their importance for contemporary science education--A pedagogical justification and the state-of-the-art in Israel, Germany, and the USA. *International Journal of Science and Mathematics Education*, *9*(6), 1459-1483. doi:10.1007/s10763-010-9273-9

Hounshell, P. B. (1987). Elementary science specialists? Definitely!. *Science and Children, 24*(4), 20,157.

Howell, D. C. (2011). *Fundamental statistics for the behavioral sciences* (7th ed.). Belmont, CA: Wadsworth.

Howie, E. K., & Stevick, E. D. (2014). The 'ins' and 'outs' of physical activity policy implementation: Inadequate capacity, inappropriate outcome measures, and insufficient funds. *Journal of School Health, 84*(9), 581-585. doi:10.1111/josh.12182

Huff, K. L., & Bybee, R. W. (2013). The practice of critical discourse in science classrooms. *Science Scope, 36*(9), 29-34.

Inhelder, B., & Piaget, J. (1969). *The psychology of the child.* (H. Weaver, Trans.). New York: Basic Books. (Original work published 1950)

Jackson, C. K., Johnson, R. C., & Persico, C. (2015). Boosting educational attainment and adult earnings: Does school spending matter after all?. *Education Next*, *15*(4), 69-76.

Jensen, J. (2012). The science of safety. *Science and Children*, *50*(4), 40-45.

Jones, G., Childers, G., Stevens, V., & Whitley, B. (2012). Citizen scientists: Investigating science in the community. *Science Teacher, 79*(9), 36-39.

Karisan, D. & Zeidler, D.L. (2017). Contextualization of nature of science within the socioscientific issues framework: A review of research. *International Journal of Education in Mathematics, Science and Technology*, *5*(2), 139-152. doi:10.18404/ijemst.270186

Katai, Z., Toth, L., & Adorjani, A. K. (2014). Multi-sensory informatics education. *Informatics in Education*, *13*(2), 225-240.

Kena, G., Hussar, W., McFarland, J., de Brey, C., Musu-Gillette, L., Wang, X., & ... American Institutes for Research, (2016). The condition of education 2016. NCES 2016-144. *National Center for Education Statistics*.

Kier, M. W., & Lee, T. D. (2017). Exploring the role of identity in elementary preservice teachers who plan to specialize in science teaching. *Teaching & Teacher Education*, 61199-210. doi:10.1016/j.tate.2016.10.016

Kirsch, C. M. (2012). Science fiction no more: Cyber warfare and the United States. *Denver Journal of International Law & Policy*, *40*(4), 620-647.

Kirst, S., & Flood, T. (2017). Research and teaching: Connecting science content and science methods for preservice elementary school teachers. *Journal of College Science Teaching, 46*(5), 49-55.

Krajcik, J., & Merritt, J. (2012). Engaging students in scientific practices: What does constructing and revising models look like in the science classroom?. *Science Scope*, *35*(7), 6-10.

Krawec, J., & Montague, M. (2014). The role of teacher training in cognitive strategy instruction to improve math problem solving. *Learning Disabilities Research & Practice (Wiley-Blackwell), 29*(3), 126-134. doi:10.1111/ldrp.12034

Lam, P., Doverspike, D., Zhao, J., Zhe, J., & Menzemer, C. (2008). An evaluation of a STEM program for middle school students on learning disability related IEPs. *Journal of STEM Education: Innovations & Research, 9*(1/2), 21-29.

Lawson, A. E. (2008). What can developmental theory contribute to elementary science instruction?. *Journal of Elementary Science Education, 20*(4), 1-14.

Lazaros, E. J. (2012). Using freely available internet resources to promote the study of science and technology in the elementary classroom. *Children's Technology & Engineering*, *17*(2), 14-17.

Lederman, N., Antink, A., & Bartos, S. (2014). Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: A pathway to developing a scientifically literate citizenry. *Science & Education*, *23*(2), 285-302. doi:10.1007/s11191-012-9503-3

Levy, A. J., Jia, Y., Marco-Bujosa, L., Gess-Newsome, J., & Pasquale, M. (2016). Science specialists or classroom teachers: Who should teach elementary science?. *Science Educator*, *25*(1), 10-21.

Marco-Bujosa, L. M., & Levy, A. J. (2016). Caught in the balance: An organizational analysis of science teaching in schools with elementary science specialists. *Science Education*, *100*(6), 983-1008.

Markworth, K. A., Brobst, J., Ohana, C., & Parker, R. E. (2016). Elementary content specialization: Models, affordances, and constraints. *International Journal of STEM Education*, *3*(16), doi:10.1186/s40594-016-0049-9

Martin, M. O., Mullis, I. V. S., Foy, P., & Hooper, M. (2016). *TIMSS 2015 International Results in Science.* Retrieved from Boston College, TIMSS & PIRLS International Study Center website: http://timssandpirls.bc.edu/timss2015/international-results/

Maxwell, D. O., Lambeth, D. T., & Cox, J. T. (2015). Effects of using inquiry-based learning on science achievement for fifth-grade students. *Asia-Pacific Forum on Science Learning and Teaching, 16*(1).

McFarland, J., Hussar, B., de Brey, C., Snyder, T., Wang, X., Wilkinson-Flicker, S., & ... American Institutes for Research, (2017). The condition of education 2017. NCES 2017-144.

McGrew, C. (2012). Engineering at the elementary level. *Technology & Engineering Teacher*, *71*(6), 19-22.

McNeill, K. L., & Pimentel, D. S. (2010). Scientific discourse in three urban classrooms: The role of the teacher in engaging high school students in argumentation. *Science Education*, *94*(2), 203-229.

Medeiros, J. A., Sanchez, G. R., & Valdez, R. B. (2012). Tough times, tough choices: The impact of the rising medical costs on the U.S. Latino electorate's health care-seeking behaviors. *Journal of Health Care for the Poor & Underserved*, *23*(4), 1383-1398. doi:10.1353/hpu.2012.0183

Milner, A., Sondergeld, T., Demir, A., Johnson, C., & Czerniak, C. (2012). Elementary teachers' beliefs about teaching science and classroom practice: An examination of pre/post NCLB testing in science. *Journal of Science Teacher Education, 23*(2), 111-132. doi:10.1007/s10972-011-9230-7

NAEP. (2015). Fourth-grade science scores changed in some states/jurisdictions in 2015 compared to 2009. Washington, DC. National Center for Education Statistics. Retrieved from http://www.air.org/resource/timss-pisa-and-naep-what-know-digging-results

Nash, I. (2015). U3A: making people scientifically literate. *Education Journal*, (233), 13-14.

National Academies of Sciences, Engineering, and Medicine. (2016). *Science literacy: Concepts, contexts, and consequences*. Washington, DC: The National Academies Press. https://doi.org/10.17226/23595.

National Academies of Sciences, Engineering, and Medicine. (2017). *Seeing students learn science: Integrating assessment and instruction in the classroom,* Washington, DC: The National Academies Press. https://doi.org/10.17226/23548.

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades k-8*. Washington, DC: The National Academies Press. https://doi.org/10.17226/11625

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Committee on Conceptual Framework for the New K-12 Science Education Standards. Board on Science Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Research Council. (2013). *Next generation science standards: For states, by states***.** Washington, DC: The National Academies Press. https://doi.org/10.17226/18290.

National Research Council. (2014). *Developing assessments for the Next Generation Science Standards*. Washington, DC: The National Academies Press. https://doi.org/10.17226/18409.

National Research Council. (2015). *Guide to implementing the next generation science standards*. Washington, DC: The National Academies Press. https://doi.org/10.17226/18802.

National Science Board. (2016). *Science and Engineering Indicators 2016*. Arlington, VA: National Science Foundation (NSB-2016-1)

Nelson, G. D., & Landel, C. C. (2007). A collaborative approach for elementary science. *Educational Leadership, 64*(4), 72-75.

Nocetti, J. (2015). Contest and conquest: Russia and global internet governance. *International Affairs*, *91*(1), 111-130. doi:10.1111/1468-2346.12189

Obama, B. H. (2009). Remarks at the national academy of sciences. *Daily Compilation of Presidential Documents*, 1.

O'Day, B. (2016). Making the transition to three-dimensional teaching: An NGSS@NSTA curator and elementary science specialist shares how to evaluate teaching materials using the equip rubric. *Science and Children*, *53*(9), 26-30.

OECD (2016a), *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic and Financial Literacy***,** OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264255425-en

OECD (2016b). PISA 2015 results in focus. Retrieved from http://www.oecd.org/pisa/pisa-2015-results-in-focus.pdf

Olkin, I. & Hotelling, H. (1960). *Contributions to probability and statistics: Essays in honor of Harold Hotelling*. Standford, CA: Stanford University Press.

Olson, J. K., & Finson, K. D. (2009). Developmental perspectives on reflective practices of elementary science education students. *Journal of Elementary Science Education, 21*(4), 43-52.

Olson, J., Tippett, C., Milford, T., Ohana, C., & Clough, M. (2015). Science teacher preparation in a north american context. *Journal of Science Teacher Education, 26*(1), 7-28. doi:10.1007/s10972-014-9417-9

Olson, S., Riordan, D. G., & Executive Office of the, P. (2012). Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Report to the President.

Parker, A., Rakes, L., & Arndt, K. (2017). Departmentalized, self-contained, or somewhere in between: Understanding elementary grade-level organizational decision-making. *Educational Forum, 81*(3), 236-255. doi:10.1080/00131725.2017.1314569

Pawlowski, S. D., & Jung, Y. (2015). Social representations of cybersecurity by university students and implications for instructional design. *Journal of Information Systems Education, 26*(4), 281-294.

Peterson, T. E. (2012). Constructivist pedagogy and symbolism: Vico, Cassirer, Piaget, Bateson. *Educational Philosophy and Theory, 44*(8), 878-891. doi:10.1111/j.1469-5812.2011.00765.x

Petty, T. M., Fitchett, P., & O'Connor, K. (2012). Attracting and keeping teachers in high-need schools. *American Secondary Education*, *40*(2), 67.

Piaget, J. (1952a). *The child's conception of number*. London: Routledge & Kegan Paul.

Piaget, J. (1952b). *The origins of intelligence in children*. New York: International Universities Press.

Piaget, J. (1954). *The construction of reality in the child* (M. Cook, Trans.). New York: Basic Books.

Piaget, J. (1954). The construction of reality in the child. — Routledge & Kegan Paul, Basic Books, London.

Piaget, J. (1962). The stages of the intellectual development of the child. *Bulletin of the Menninger Clinic, 26,* 120-128.

Piaget, J. (1972). *The principles of genetic epistemology.* London: Routledge and Kegan Paul.

Piaget, J. (1977). *The development of thought: Equilibration of cognitive structures.* New York: The Viking Press.

Pryor, B. W., Pryor, C. R., & Rui, K. (2016). Teachers' thoughts on integrating STEM into social studies instruction: Beliefs, attitudes, and behavioral decisions. *Journal of Social Studies Research, 40*(2), 123-136. doi:10.1016/j.jssr.2015.06.005

Qarareh, A. O. (2016). The effect of using the constructivist learning model in teaching science on the achievement and scientific thinking of 8th grade students. *International Education Studies*, *9*(7), 178-196.

Ramey-Gassert, L., Shroyer, M. G., & Staver, J. R. (1996). A qualitative study of factors influencing science teaching. *Science Education, 80*(3), 283.

Ravanis, K. (2017). Early childhood science education: State of the art and perspectives. *Journal of Baltic Science Education, 16*(3), 284-288.

Rhoton, J., Field, M. H., & Prather, J. P. (1992). An alternative to the elementary school science specialist. *Journal of Elementary Science Education, 4*(1), 14-25.

Roberts, D.A. & Bybee, R.W. (2014). Scientific literacy, science literacy, and science education. In Lederman, N. G., & Abell, S. K. (2014) *Handbook of research on science education: Volume II* (pp. 697-726). New York: Routledge.

Rutherford, F. & Ahlgren, A. (1990). *Science for all Americans*. New York: Oxford University Press.

Sahin, E. A., & Deniz, H. (2016). Exploring elementary teachers' perceptions about the developmental appropriateness and importance of nature of science aspects. *International Journal of Environmental and Science Education, 11*(9), 2673-2698. doi:10.12973/ijese.2016.715a

Sampson, V., Grooms, J., & Enderle, P. (2013). Development and initial validation of the beliefs about reformed science teaching and learning (BARSTL) questionnaire. *School Science and Mathematics, 113*(1), 3-15. doi:10.1111/j.1949-8594.2013.00175.x

Schmitt, N. (2013). The effects of teaching experience on high school education: A statistical model on factors of educational achievement in math and science. *American Journal of Agricultural Economics, 95*(2), 531-535. doi: 10.1093/ajae/aas101

Scott, C. M. (2016). Using Citizen Science to Engage Preservice Elementary Educators in Scientific Fieldwork. *Journal of College Science Teaching, 46*(2), 37-41.

Settlage, J., Butler, M. B., Wenner, J., Smetana, L. K., & McCoach, B. (2015). Examining elementary school science achievement gaps using an organizational and leadership perspective. *School Science & Mathematics, 115*(8), 381-391. doi:10.1111/ssm.12144

Simpkins, S. D., Fredricks, J. A., & Eccles, J. S. (2012). Charting the Eccles' expectancy-value model from mothers' beliefs in childhood to youths' activities in adolescence. *Developmental Psychology, 48*(4), 1019-1032. doi:10.1037/a0027468

Smith, D. C., & Anderson, C. W. (1999). Appropriating scientific practices and discourses with future elementary teachers. *Journal of Research in Science Teaching, 36*(7), 755-776.

Smith, J., & Nadelson, L. (2017). Finding alignment: The perceptions and integration of the next generation science standards practices by elementary teachers. *School Science & Mathematics, 117*(5), 194-203. doi:10.1111/ssm.12222

Smith, P. S., Trygstad, P. J., & Banilower, E. R. (2016). Widening the gap: Unequal distribution of resources for K-12 science instruction. *Education Policy Analysis Archives*, *24*(8). doi:10.14507/epaa.v24.2207

Steinberg, R., Wyner, Y., Borman, G., & Salame, I. I. (2015). Targeted courses in inquiry science for future elementary school teachers. *Journal of College Science Teaching, 44*(6), 51-56.

Swartz, C. E. (1987). Elementary science specialists? We know better. *Science and Children, 24*(4), 21,157.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Boston, MA: Allyn and Bacon.

Travis, F. (2016). Transcending as a driver of development. *Annals of the New York Academy of Sciences, 1373*(1), 72-77. doi:10.1111/nyas.13071

VanLehn, K. (2013). Model construction as a learning activity: A design space and review. *Interactive Learning Environments, 21*(4), 371-413. doi:10.1080/10494820.2013.803125

Varma, K. (2014). Supporting scientific experimentation and reasoning in young elementary school students. *Journal of Science Education & Technology, 23*(3), 381-397. doi:10.1007/s10956-013-9470-8

Wadsworth, B. J. (1996). *Piaget's theory of cognitive and affective development* (5th ed.). White Plains, NY: Longman.

Wallace, C. S., & Coffey, D. (2016). Science in sync: Integrating science with literacy provides rewarding learning opportunities in both subjects. *Science and Children, 53*(8), 36-41.

Walpole, S., & McKenna, M. C. (2017). *How to plan differentiated reading instruction: Resources for grades k-3*. New York: The Guilford Press.

Warner, R.M. (2013). *Applied statistics: From bivariate through multivariate techniques.* Los Angeles: Sage.

Wenner, J. J. (2017). Urban elementary science teacher leaders: responsibilities, supports, and needs. *Science Educator, 25*(2), 117-125.

Williams, D. H. (1990). Making a case for the science specialist. *Science and Children*, 2730-32.

Wilson, R., & Kittleson, J. (2012). The role of struggle in pre-service elementary teachers' experiences as students and approaches to facilitating science learning. *Research in Science Education*, *42*(4), 709-728. doi:10.1007/s11165-011-9221-x

Wissehr, C., Concannon, J., & Barrow, L. H. (2011). Looking back at the sputnik era and its impact on science education. *School Science and Mathematics*, *111*(7), 368-375. doi:10.1111/j.1949-8594.2011.00099.x

Zehr, N. A. (2013). Moral landscapes and ethical vistas moral landscapes and ethical vistas: American responses to the war on terror. *Journal of Religious Ethics, 41*(3), 514-539. doi:10.1111/jore.12027

APPENDICES

APPENDIX A. IRB Approval Letter

LIBERTY UNIVERSITY.
INSTITUTIONAL REVIEW BOARD

May 30, 2018

Wesley A. Roach
IRB Application 3206: The Impact of Using Elementary Science Specialists on 5th Grade Science Achievement Scores

Dear Wesley A. Roach,

The Liberty University Institutional Review Board has reviewed your application in accordance with the Office for Human Research Protections (OHRP) and Food and Drug Administration (FDA) regulations and finds your study does not classify as human subjects research. This means you may begin your research with the data safeguarding methods mentioned in your IRB application.

Your study does not classify as human subjects research because it will not involve the collection of identifiable, private information.

Please note that this decision only applies to your current research application, and any changes to your protocol must be reported to the Liberty IRB for verification of continued non-human subjects research status. You may report these changes by submitting a new application to the IRB and referencing the above IRB Application number.

If you have any questions about this determination or need assistance in identifying whether possible changes to your protocol would change your application's status, please email us at irb@liberty.edu.

Sincerely,

signature removed

G. Michele Baker, MA, CIP
Administrative Chair of Institutional Research
The Graduate School

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APPENDIX B. School Science Instruction Questionnaires for Principals

School Science Instruction Questionnaire

This questionnaire is designed to help determine which schools may be suitable for a study related to science instruction for fifth grade students.

1. What is the name of your school? [redacted] School A
2. What is the address of your school? __[redacted] Georgia
3. To what school district does your school belong? __[redacted] School District A __________
4. What is your name? __[redacted] Principal A ______________________
5. What is your position/title at the school? __Principal ___________________________________
6. What is your phone number? _[redacted]_______________________________________
7. Approximately how many students attend your school? __800 ____________
8. Place a checkmark next to the statement below that best describes who taught science to fifth grade students at your school for the 2016-2017 school year:
   __X__ A. Our students received science instruction only from regular homeroom teachers.
   _____ B. Our students received science instruction only from a science specialist.
   _____ C. Our students received science instruction from both regular homeroom teachers AND also from a science specialist.
9. Place a checkmark next to the statement below that best describes the fifth grade classes at your school for the 2016-2017 school year:
   __X__ A. Each of our fifth grade classes is taught mainly by a single teacher (self-contained).
   __X__ B. Our fifth grade classes are departmentalized so that two or more teachers work together on teams. (Please describe the subjects taught by the teachers on your fifth grade departmentalized teams below.)
   __Two gifted teachers team teach and the other 3 are self-contained.____________

If you answered B or C for question #8 above, please also answer questions 10-14 below based on the 2016-2017 school year.

10. Approximately how many times per week did each fifth grade class receive instruction from the science specialist? ____________
11. On the day(s) that fifth grade classes received instruction from the science specialist, approximately how many minutes was each class? ______________
12. Where did fifth grade classes receive instruction from the science specialist?
    ___ in the regular homeroom classroom ___ in a separate science classroom
13. Approximately how many minutes per week were allocated for science instruction from regular fifth grade homeroom teachers (not the science specialist)? _______________
14. Please place a checkmark next to all of the statements below that are true of the science specialist at your school for the 2016-2017 school year:
    ___ A. The science specialist did not teach anything else besides science.
    ___ B. The science specialist served as a science resource person for regular homeroom teachers.
    ___ C. The science specialist collaborated with regular homeroom teachers.
    ___ D. The science specialist helped provide oversight of the science curriculum at your school.
    ___ E. The science specialist's instruction was aligned with regular homeroom teachers' science instruction.
    ___ F. The science specialist regularly engaged students with hands-on, inquiry based learning.
    ___ G. The science specialist had received extra training in science content and/or instruction.

School Science Instruction Questionnaire

This questionnaire is designed to help determine which schools may be suitable for a study related to science instruction for fifth grade students.

1. What is the name of your school? [redacted] School B
2. What is the address of your school? __[redacted] Georgia
3. To what school district does your school belong? ___[redacted] School District A ___________
4. What is your name? ___[redacted]___Principal B _______________________
5. What is your position/title at the school? ___Principal ____________________________________
6. What is your phone number? __[redacted]____
7. Approximately how many students attend your school? ____480 ___________
8. Place a checkmark next to the statement below that best describes who taught science to fifth grade students at your school for the 2016-2017 school year:
   __X__ A. Our students received science instruction only from regular homeroom teachers.
   _____ B. Our students received science instruction only from a science specialist.
   _____ C. Our students received science instruction from both regular homeroom teachers AND also from a science specialist.
9. Place a checkmark next to the statement below that best describes the fifth grade classes at your school for the 2016-2017 school year:
   __X__ A. Each of our fifth grade classes is taught mainly by a single teacher (self-contained).
   _____ B. Our fifth grade classes are departmentalized so that two or more teachers work together on teams. (Please describe the subjects taught by the teachers on your fifth grade departmentalized teams below.)
   ____

If you answered B or C for question #8 above, please also answer questions 10-14 below based on the 2016-2017 school year.

10. Approximately how many times per week did each fifth grade class receive instruction from the science specialist? _____________
11. On the day(s) that fifth grade classes received instruction from the science specialist, approximately how many minutes was each class? ______________
12. Where did fifth grade classes receive instruction from the science specialist?
    ___ in the regular homeroom classroom ___ in a separate science classroom
13. Approximately how many minutes per week were allocated for science instruction from regular fifth grade homeroom teachers (not the science specialist)? ________________
14. Please place a checkmark next to all of the statements below that are true of the science specialist at your school for the 2016-2017 school year:
    ___ A. The science specialist did not teach anything else besides science.
    ___ B. The science specialist served as a science resource person for regular homeroom teachers.
    ___ C. The science specialist collaborated with regular homeroom teachers.
    ___ D. The science specialist helped provide oversight of the science curriculum at your school.
    ___ E. The science specialist's instruction was aligned with regular homeroom teachers' science instruction.
    ___ F. The science specialist regularly engaged students with hands-on, inquiry based learning.
    ___ G. The science specialist had received extra training in science content and/or instruction.

School Science Instruction Questionnaire

This questionnaire is designed to help determine which schools may be suitable for a study related to science instruction for fifth grade students.

1. What is the name of your school? [redacted] School C
2. What is the address of your school? _[redacted] Georgia
3. To what school district does your school belong? __[redacted] School District B ___________
4. What is your name? __[redacted] __Principal C_______________________
5. What is your position/title at the school? __Principal ____________________________________
6. What is your phone number? _[redacted] ___________________________________
7. Approximately how many students attend your school? __380________
8. Place a checkmark next to the statement below that best describes who taught science to fifth grade students at your school for the 2016-2017 school year:
   _____ A. Our students received science instruction only from regular homeroom teachers.
   __X__ B. Our students received science instruction only from a science specialist.
   _____ C. Our students received science instruction from both regular homeroom teachers AND also from a science specialist.
9. Place a checkmark next to the statement below that best describes the fifth grade classes at your school for the 2016-2017 school year:
   _____ A. Each of our fifth grade classes is taught mainly by a single teacher (self-contained).
   __X__ B. Our fifth grade classes are departmentalized so that two or more teachers work together on teams. (Please describe the subjects taught by the teachers on your fifth grade departmentalized teams below.)
   ____Each teacher teaches one subject: Math, ELA, Social Studies, or Science____

If you answered B or C for question #8 above, please also answer questions 10-14 below based on the 2016-2017 school year.

10. Approximately how many times per week did each fifth grade class receive instruction from the science specialist?
    ______5_______
11. On the day(s) that fifth grade classes received instruction from the science specialist, approximately how many minutes was each class? ____75________
12. Where did fifth grade classes receive instruction from the science specialist?
    ___ in the regular homeroom classroom   _x_ in a separate science classroom
13. Approximately how many minutes per week were allocated for science instruction from regular fifth grade homeroom teachers (not the science specialist)? _____0__________
14. Please place a checkmark next to all of the statements below that are true of the science specialist at your school for the 2016-2017 school year:
    _x_ A. The science specialist did not teach anything else besides science.
    _x_ B. The science specialist served as a science resource person for regular homeroom teachers.
    _x_ C. The science specialist collaborated with regular homeroom teachers.
    _x_ D. The science specialist helped provide oversight of the science curriculum at your school.
    ___ E. The science specialist's instruction was aligned with regular homeroom teachers' science instruction.
    _x_ F. The science specialist regularly engaged students with hands-on, inquiry based learning.
    _x_ G. The science specialist had received extra training in science content and/or instruction.

School Science Instruction Questionnaire

This questionnaire is designed to help determine which schools may be suitable for a study related to science instruction for fifth grade students.

1. What is the name of your school? [redacted] School D
2. What is the address of your school? __[redacted] Georgia
3. To what school district does your school belong? ___[redacted] School District B ___________
4. What is your name? ___[redacted] Principal D ______________________
5. What is your position/title at the school? ___Principal ______________________________________
6. What is your phone number? __[redacted] ______________________________________

1. Approximately how many students attend your school? ___485 ____________
2. Place a checkmark next to the statement below that best describes who taught science to fifth grade students at your school for the 2016-2017 school year:
   _____ A. Our students received science instruction only from regular homeroom teachers.
   _____ B. Our students received science instruction only from a science specialist.
   __X__ C. Our students received science instruction from both regular homeroom teachers AND also from a science specialist.
3. Place a checkmark next to the statement below that best describes the fifth grade classes at your school for the 2016-2017 school year:
   _____ A. Each of our fifth grade classes is taught mainly by a single teacher (self-contained).
   __X__ B. Our fifth grade classes are departmentalized so that two or more teachers work together on teams. (Please describe the subjects taught by the teachers on your fifth grade departmentalized teams below.)
   ___Mathematics, Reading/ELA, Science, Social Studies ________________________________

If you answered B or C for question #8 above, please also answer questions 10-14 below based on the 2016-2017 school year.

4. Approximately how many times per week did each fifth grade class receive instruction from the science specialist?
   ___They go to the STEM Lab (science specialist) one week per month for the entire week during Activity/Specials___
5. On the day(s) that fifth grade classes received instruction from the science specialist, approximately how many minutes was each class? __55 Minutes _________
6. Where did fifth grade classes receive instruction from the science specialist?
   ___ in the regular homeroom classroom __X__ in a separate science classroom
7. Approximately how many minutes per week were allocated for science instruction from regular fifth grade homeroom teachers (not the science specialist)? __325 Minutes _________
8. Please place a checkmark next to all of the statements below that are true of the science specialist at your school for the 2016-2017 school year:
   _X_ A. The science specialist did not teach anything else besides science.
   _X_ B. The science specialist served as a science resource person for regular homeroom teachers.
   _X_ C. The science specialist collaborated with regular homeroom teachers.
   ___ D. The science specialist helped provide oversight of the science curriculum at your school.
   _X_ E. The science specialist's instruction was aligned with regular homeroom teachers' science instruction.
   _X_ F. The science specialist regularly engaged students with hands-on, inquiry based learning.
   _X_ G. The science specialist had received extra training in science content and/or instruction.

APPENDIX C. Principal Notification Letter

May 29, 2018

[redacted]

Dear [redacted]:

I am a doctoral student at Liberty University. I am conducting a study related to elementary science instruction. The study will compare the achievement of students from schools where science specialists provide instruction to schools where generalists provide science instruction. Your school is one of four from northeast Georgia that will be included in the study. I have checked with the Georgia Department of Education (GADOE) and learned that the data needed for my study are publicly available by request. For that reason, my study will not require that you or your staff provide any data. The GADOE has assured me that they will remove any identifying information before they send me the data. I wanted to assure you that not only will none of your students be identifiable in the study, but also that your school will not be identifiable in the study. I will use pseudonyms when referring to the schools in the study.

Thank you for your service to the students in your school. Please feel free to call on me if you have questions or if I may in any other way be of assistance to you.

Sincerely,

signature removed

Wesley A. Roach